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Final report

A financial assessment of recycling mixed plastics in the UK

Financial modelling and assessment of mixed plastics separation and reprocessing on a commercial scale in the UK

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WRAP helps individuals, businesses and local authorities to reduce waste and recycle more, making better use of resources and helping to tackle climate change.

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Front cover photography: Plastic film from household packaging

Executive summary

This final report presents the financial models developed for both the Material Recovery Facility (MRF) and plastic sorting and reprocessing facility elements of the WRAP (Waste & Resources Action Programme) commercial scale mixed plastics recycling project.

The term “mixed plastics” covers plastic packaging typically found in the household waste bin such as trays, tubs, pots and films but excludes plastic bottles and non-packaging items.

The financial modelling work includes plastic bottles as well as mixed plastics in the feed stream to the processing facilities. This is because plastic bottles often arise in the waste stream along with mixed plastics and during the recycling process plastic bottles frequently end up in the same separated stream as other rigid plastics such as trays. The full range of plastic packaging including bottles, other rigids and film that is collected from households is referred to as Household Plastics Packaging.

The work models three MRF formats and a number of scenarios for a plastics recycling facility.

The MRF models indicate that satisfactory returns can be earned from investing in the separation of a mixed plastics and bottle stream by UK MRFs that currently process mixed dry recyclables.

The integrated plastic sorting and reprocessing plant model consists of a Plastics Recovery Facility (PRF) which sorts the plastic into different fractions for recycling, and a reprocessing facility which processes the sorted streams into high grade usable outputs. The modelling indicates that satisfactory returns can be earned from investment in a large scale integrated plastic PRF and reprocessing facility for the mixed plastics and bottle stream provided by a MRF.

MRF model

Three financial models have been constructed for the MRF element of this project:

- A fully manual MRF, where all sorting of material is done by hand; and
- A semi-automated MRF, where plastic films are removed by hand at the start of the sorting process and then Polyethylene Terephthalate (PET) and High Density Polyethylene (HDPE) bottles and mixed rigid containers are identified and separated automatically by Near Infra Red (NIR) sorting technology.
- A fully automated MRF for the special case where paper and card are stored by householders in separate bins and collected separately from other dry recyclables (glass, cans, plastic bottles and other mixed plastics including films).

The projections from the models indicate that a typical manual MRF handling paper, cardboard, metals and plastics – but not a glass stream – with a nominal capacity of 10t/hr and an actual throughput of approximately 7t/hr will require a subsidy of around £9/t of all dry recyclables for a local authority operated MRF in addition to the avoided landfill costs of £58/t. A commercial MRF would require an incremental gate fee of about £120/t of additional mixed plastic feed including bottles in order to justify the level of investment required in a manual picking operation for mixed plastics and bottles.

In comparison, the model for a semi-automated MRF, with the same capacity and feed mix, will require no subsidy for a local authority operated MRF over the avoided landfill cost, and for a commercial MRF, an incremental gate fee of around £32/t of additional mixed plastics and bottles in the feed in order for the investment to be attractive.

Although not in common use a fully automated MRF for a mixed dry recyclable collection that includes mixed plastics and bottles but excludes paper and card would have very attractive returns and require no subsidy over avoided landfill cost for a local authority operated MRF and should be able to accept the additional mixed plastics and bottles in the feed without a gate fee.

Integrated Plastics Recovery Facility (PRF) and reprocessing model

The financial model for the combined mixed plastics PRF and reprocessing facility was developed using data collected by Nextek from practical trials at a UK PRF and from several specialist packaging plastic reprocessing plants in the UK and elsewhere in Europe.

A single financial model was constructed for the integrated PRF and reprocessing element of this project. The projections model an integrated PRF and plastic reprocessing plant which includes the following elements:

- A semi-automated PRF section, where plastic films are removed by hand at the start of the sorting process and then PET, HDPE, PP, PS and PVC rigid containers are identified and separated automatically by Near Infra Red sorting technology. The PRF section produces separated rigid container fractions (including bottles) and a film fraction for further processing within the integrated PRF and reprocessing facility, plus a baled PVC fraction for sale. Note that part of the films processed by the integrated facility will be supplied separately from the baled mixed plastics by the primary MRFs because a large proportion of the films are removed at the MRF as a separate stream prior to paper and card sorting;
- A flake washing plant which dry cleans and granulates segregated rigid plastics from the PRF section and then washes and separates the material further to produce clean washed single polymer flake fractions for further processing;
- An extrusion section which melts and vacuum degasses (where appropriate) the clean washed flake to produce food grade natural PET, food grade natural HDPE, and non food grade but high quality PP, PS, mixed colour (Jazz) PET and Jazz PE pellet products for sale;
- A Near Infra Red film sorting section which separates the film fraction produced by the MRF; and
- A film washing, agglomeration and extrusion section which produces clean Low Density Polyethylene (LDPE) pellet for sale.

Under the model assumptions and current (2009) conditions the projections indicate that an integrated PRF and reprocessor with a base case throughput of 80,000t/yr of mixed plastics from household recyclable collections (including mixed rigid, bottles and film fractions) should be able to provide a satisfactory return on investment, with a total project cost of around £29 million.

Conclusions

Collecting and separating mixed household recyclable plastics appears to be able to generate commercially viable investor returns in the UK provided the integrated Plastics Recovery Facility and reprocessing operations which are supplied by the primary MRFs operate at a scale of at least 80,000t/yr.

The financial modelling exercise indicates that the more attractive arrangement is for MRFs to separate films as one fraction and mixed rigid plastics (including bottles) as the other, with minimal further processing. A semi - automated MRF would not require any subsidy above avoided landfill cost in the case of a local authority operated MRF and an incremental gate fee of £9/t for the mixed plastic part of the feed to a commercial MRF in order to generate a satisfactory investor return. If the MRF is large (over 20t/hr capacity) it should be possible to justify using NIR sorting technology at the MRF to separate clear PET and natural HDPE for sale as segregated bales.

The MRF models demonstrate that there could be a substantial reduction in separation costs at the MRF if paper and card can be segregated by householders and collected separately from other dry recyclables at kerbside.

A stand-alone near infra red sorting plant (a PRF) which takes in plastic bottles and other rigid plastics and produces segregated, baled containers of single polymer type for export or processing by others needs to be at a scale of around 80,000t/yr to make a positive return but with a substantially lower capital cost of around £7.8million compared to £29million for a full integrated PRF and reprocessing facility.

A dedicated PRF and plastics reprocessing facility that handles only mixed rigid plastics which have been pre-sorted in a separate MRF to remove films, clear PET and natural HDPE appears to be commercially viable at a scale of around 50,000t/yr.

A fully integrated plastics recovery and reprocessing facility producing high grade clear PET and natural HDPE and industrial grade PE, LDPE, coloured PET, PS and PP appears to be able to generate adequate investor returns at a scale of about 80,000t/yr with an estimated base case project internal rate of return (IRR) of 19% and a capital cost of around £29million.

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Glossary

MRF	Materials recycling/reclamation facility
PRF	Plastics Recovery Facility (separation plant that sorts mixed plastics, including bottles and other rigids by polymer type and colour)
Reprocessing facility	Processes the sorted streams from a PRF into usable polymer outputs (can include colour separation, washing, extrusion, compounding).
PRN/PERN	Packaging recovery note/ Packaging export recovery note
NIR	Near Infra Red
Jazz	In the context of plastic recycling Jazz means 'mixed colours'

1.0 Introduction

1.1 Background

WRAP commissioned a research programme to investigate the technical and commercial viability of developing an integrated mixed plastic waste management solution in the UK and to demonstrate whether it is possible for such an operation to be commercially sustainable in the UK. The project also sought to understand the role of Material Recovery Facilities (MRFs) in supplying mixed plastic waste for recycling, in terms of equipment and processes needed and whether MRFs can handle mixed plastics in an economically sustainable way.

The project was divided in to three lots:

- Lot 1: MRF processing trials;
- Lot 2: Commercial scale recycling trials and management of residue; and
- Lot 3: Economic and financial assessment of the business case.

Axion Consulting has delivered the work in lot 3 for WRAP, with Nextek and a number of project partners delivering the trials in lots 1 and 2.

1.2 Aims and objectives of project

The aim of this part of the overall project (Lot 3) is to undertake an economic and financial sustainability assessment of the processes and facilities identified in the lot 1 and 2 trials.

The objectives of the project were:

- Evaluate and demonstrate the economic viability of processing mixed plastics in a MRF to generate a mixed plastic output from a comingled domestic waste input to be used as a raw material in a mixed plastic sorting (PRF) and reprocessing plant; and
- Conduct a detailed and robust investment appraisal for setting up and operating a mixed plastic sorting (PRF) and reprocessing plant within the UK, with a minimum processing capacity of 40,000 t/annum.

1.3 Project methodology

Axion has developed separate financial projections which model the returns from investments made in both MRFs and mixed plastics PRF and reprocessing facilities.

The term “mixed plastics” covers plastic packaging typically found in the household waste bin such as trays, tubs, pots and films but excludes plastic bottles and non-packaging items.

The financial modelling work includes plastic bottles as well as mixed plastics in the feed stream to the processing facilities. This is because plastic bottles often arise in the waste stream along with mixed plastics and during the recycling process plastic bottles frequently end up in the same separated stream as other rigid plastics such as trays. The full range of plastic packaging including bottles, other rigids and film that is collected from households is referred to as Household Plastics Packaging.

The models for the MRF element cover manual, semi-automated and fully automated operation. The first two cases apply to collections where paper and card are collected with other dry recyclables so manual removal of plastic films is required. The last case, although not in common use applies to the special scenario where paper and card are collected separately from other dry recyclables. The MRF models are incremental cash flow models. They model the effect of adding mixed plastic separation capability to an existing MRF which already separates and processes cardboard, paper, metals and potentially glass from a mixed dry recyclables stream.

The integrated Plastics Recovery facility (PRF) and reprocessing plant model is a full profit and loss, cash flow and balance sheet projection model, for a stand alone new build integrated plastics recycling facility.

The model also includes an incremental cash flow only forecast in a similar format to the MRF model for investment in mixed plastics reprocessing as an 'add on' facility to an existing reprocessing plant.

The models are based on operational data supplied to Axion by Nextek and its project partners from their work in lots 1 and 2. In certain cases Axion has made estimates of some cost and revenue parameters based on its own operational experience of running a plastics recycling business.

1.4 MRF element

The MRF models have been constructed to predict the likely financial returns that can be realised if an existing household waste MRF invests in the separation of a mixed plastics stream.

Three basic MRF models have been constructed:

- A fully manual MRF, where all sorting of material is done by hand; and
- A semi-automated MRF, where plastic films are removed by hand at the start of the sorting process and then PET and HDPE bottles and mixed rigid containers are identified and separated automatically by Near Infra Red (NIR) sorting technology (no viable automatic process to separate plastic films from paper and card appears to be available presently).
- A fully automated MRF for the special case where paper and card are stored by householders in separate bins and collected separately from other dry recyclables (glass, cans, plastic bottles and other mixed plastics including films)

Figure 1 Flowsheet for MRF with manual plastic separation

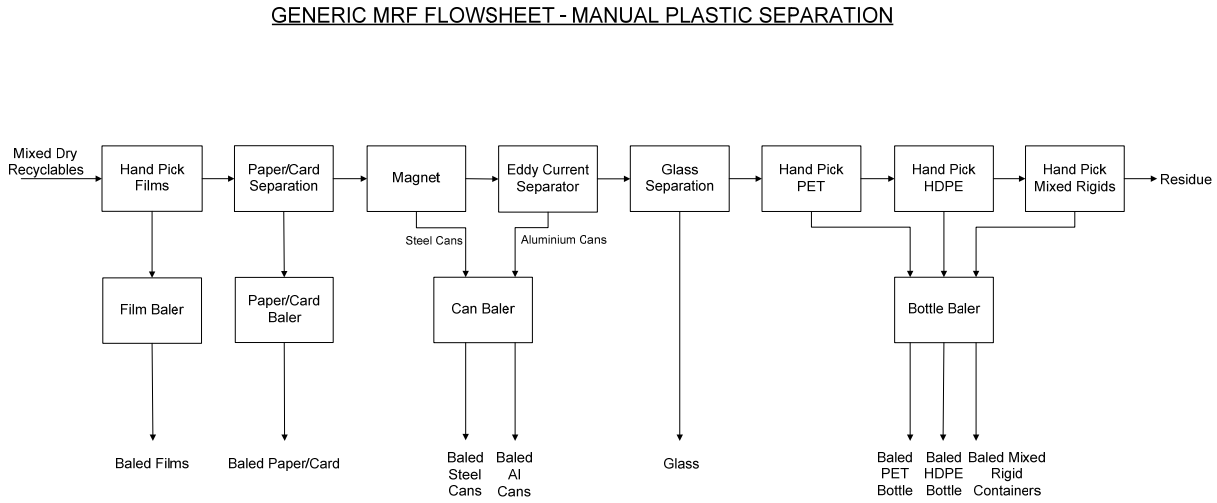


Figure 2 Flowsheet for semi-automatic MRF with NIR sorting for rigid plastics

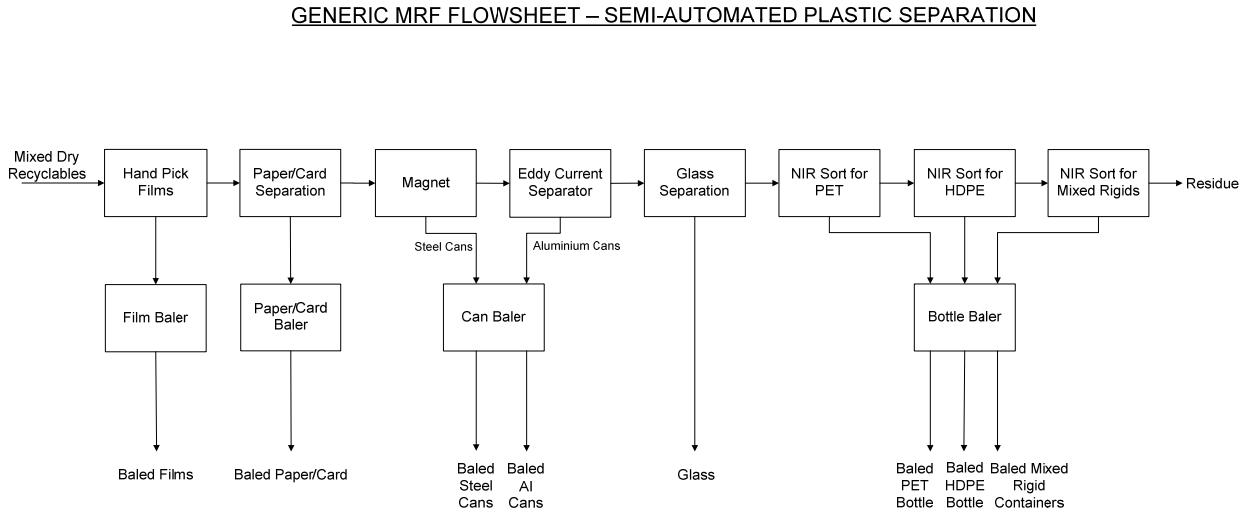
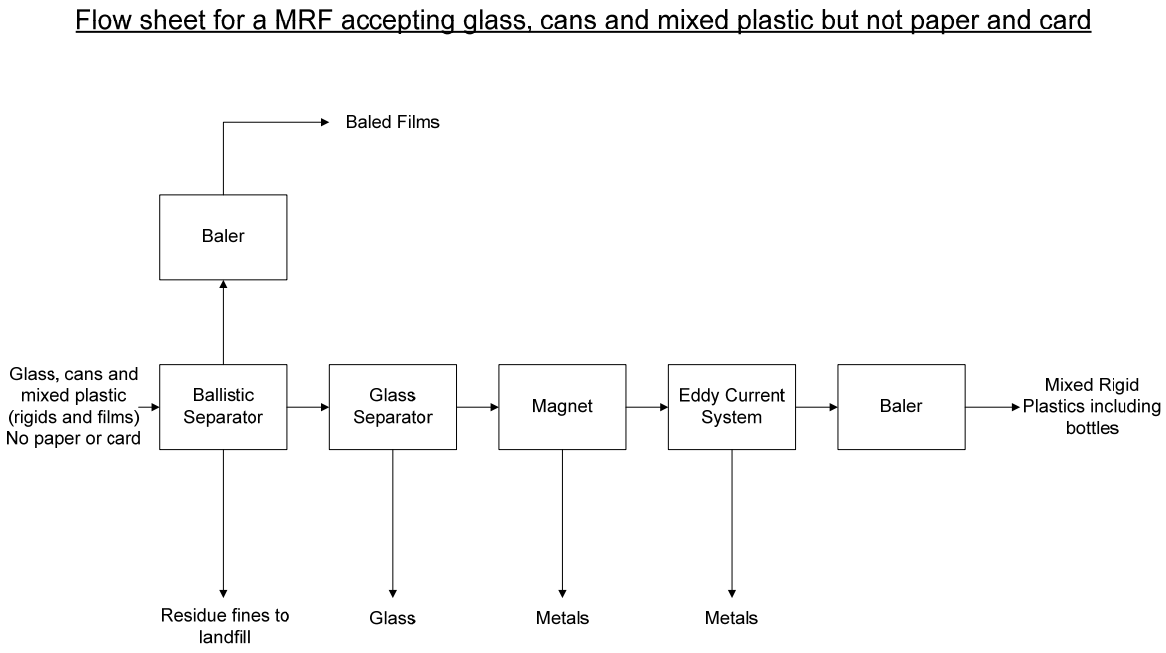


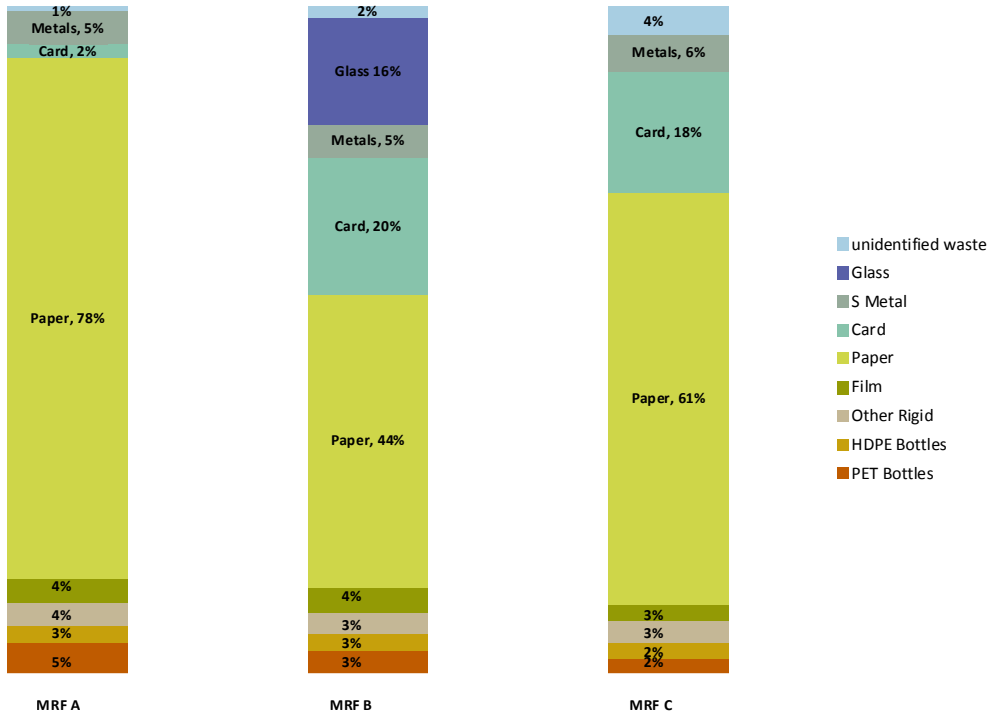
Figure 3 Flowsheet for fully automatic MRF where paper and card are collected separately from mixed plastics



Note that this separation arrangement was not tested by Nextek during the Lot 1 trials and would need to be proven in practical trials before it could be recommended without reservations.

The composition of the feed in the MRF model was estimated by Nextek and Bowman process technology from the results of the practical trials that they conducted on three UK MRFs that process mixed plastics. The feed compositions for the three MRFs are shown below:

Figure 4 Feed compositions estimated for the three MRFs tested in this project

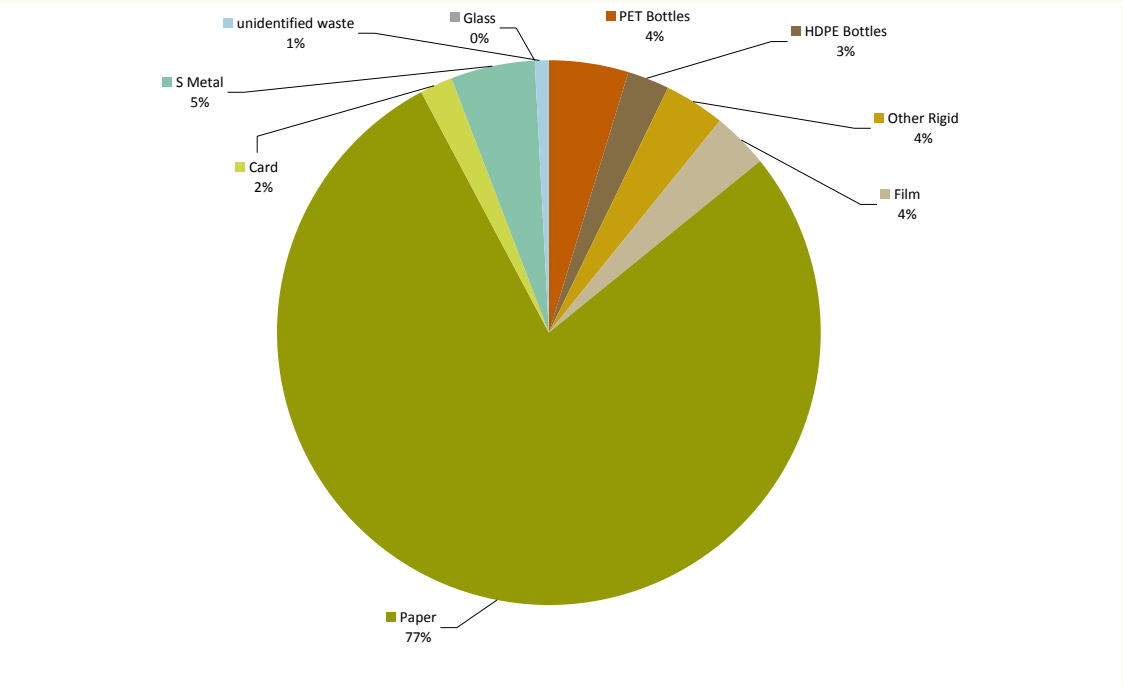


Note that the total percentage of paper and card in the feed for all three MRFs is in the range 76-80% when the paper and card content is adjusted for the 16% glass processed by MRF B.

The models assume that mixed plastics (film and rigid) and bottles make up 14% of the total input of material into the MRFs.

The feed mix assumed for the MRF model includes bottles, other rigid plastics and film and is the composition measured for MRF A, adjusted for increased film content. The film content is adjusted because at present the collection instruction to households in the catchment area for MRF A is that they should not include films. It was felt by Nextek and Bowman Process Technology that this composition would be most representative for future large scale household mixed plastic collections.

Figure 5 Feed mix assumed in the MRF model



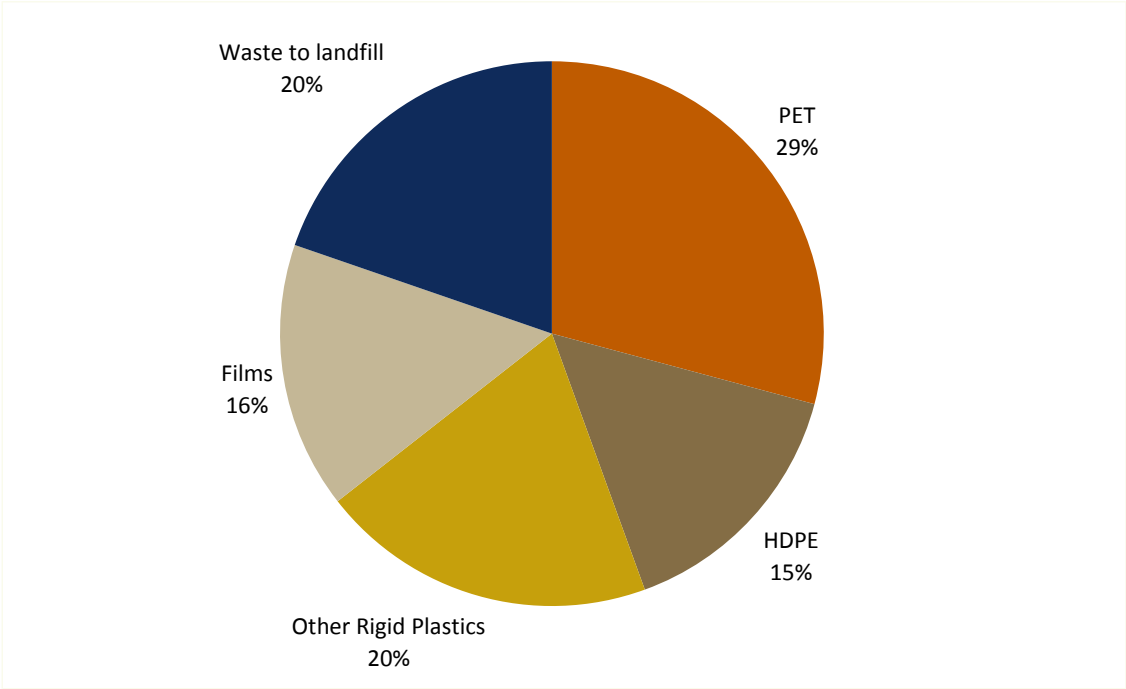
The MRF model assesses the financial impact of adding mixed plastic processing to an existing MRF that already separates paper, card and metal so the costs and revenues associated with recovering paper, card and metal are excluded.

Note it was assumed that the manual and semi-automated MRFs would not process glass, although one of the three MRFs trialled did process glass comingled with other recyclables.

The feed composition in the model for the fully automated MRF was estimated from the composition for MRF B (which does collect glass). This composition was adjusted to remove paper and card so that the feed to the MRF in this scenario included only PET and HDPE bottles, plastic films, other rigid plastics, cans and glass.

The mix of plastic products produced by the MRF is calculated in the MRF model based on the sorting efficiencies of the manual or automated sorters as appropriate:

Figure 6 Output plastic product mix from the base case semi-automated MRF



The base case throughput assumed in the MRF model is 10te/hr of mixed dry recyclables, including paper, card and metals as this is the approximate throughput that was measured for MRF A. This equates to about 1.5te/hr of mixed plastics.

Note that in all cases the PET product from the MRF includes a mixture of bottle and non-bottle rigid PET containers. Likewise the HDPE product from the MRF contains a mix of bottle and non-bottle rigid HDPE containers.

In the case of the semi-automated MRF the NIR sorter may be configured to extract either only clear PET bottles and clear non-bottle PET rigids or both clear and coloured PET. The same applies for HDPE. The models assume that the NIR sorters are configured to extract both clear and coloured material. The cost of a NIR sorter to differentiate both polymer type and colour in order to separate clear polymer only is about 20% more than a sorter which will identify only polymer type.

1.5 Integrated mixed plastics recovery facility (PRF) and reprocessing plant

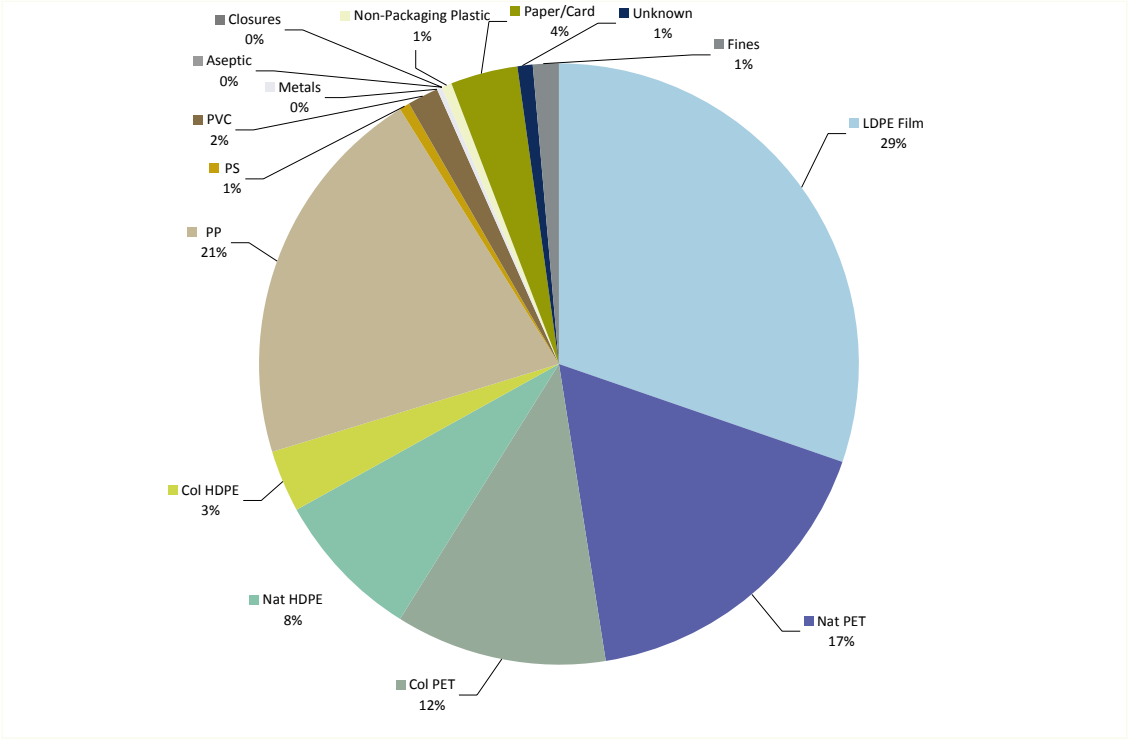
The financial model for the integrated mixed plastics recovery (PRF) and reprocessing plant assesses the investment in two ways:

- as a stand-alone new build mixed plastics sorting (PRF) and reprocessing plant; and
- as the addition of mixed plastics sorting and reprocessing functionality to an existing recycling or sorting operation.

The outline mass balance data was supplied to Axion by Nextek. Axion prepared a revised mass balance from this information. The throughput and feed mix for the integrated PRF and reprocessing facility can be changed in the model for sensitivity analysis. However the base case throughput used in the model is 80,000t/yr, comprising 56,000t/yr of mixed rigid plastics and 24,000t/yr of films. This equates to a throughput of 10t/hr on a 24 hour per day, 7 day per week production system.

The feed composition for the integrated PRF and reprocessing plant was calculated by Axion using data collected by Nextek from large scale trials on a UK PRF. These trials processed mixed plastics collected from the three MRFs that were trialled in the MRF phase of the project plus additional material from other UK mixed household plastic collections. This resulted in the following composition for the mixed plastics feed in the base case model:

Figure 7 Input plastic mix for the base case integrated PRF and processing plant model



2.0 MRF generic model

2.1 Overview of model

The MRF model is a cash flow based projection which models the incremental cash flows resulting from investment by an existing dry recyclables household waste MRF in additional capacity to process a mixed plastics waste stream.

It has been assumed that the waste collection authority will introduce a full range of mixed plastics to an existing kerbside recycling service, which will already be collecting paper, cardboard, metals and possibly glass. It is assumed that plastics separation will be integrated with the existing MRF separation process. The bulk of the film fraction would be separated first by hand as this would otherwise contaminate the paper and card fractions. After separation of paper, card, steel containers, aluminium containers and (if included) glass containers using existing facilities in the MRF the remaining mixed rigid plastics would be separated either at new hand picking stations or by new automated near infra red sorters. The rigid plastics would be separated into three streams:

- Clear PET bottles
- Natural HDPE bottles
- Other mixed rigid containers

The financial model projects cash flow inflows and outflows for the project over either a ten year or five year period and makes estimates for the internal rate of return (IRR) and the net present value (NPV) of the investment in mixed plastic processing capacity over these periods.

It is assumed that the additional processing and sorting equipment will be funded by a five year lease, on normal commercial terms, with a residual value of 20% after five years. After the initial five year period it is assumed that the residual value is paid off at the same cost of finance for a further five year period. Any building work required is assumed to be self-funded by the MRF, but the costs have been included in the financial return calculations and analysis.

The model shows that the MRF is not profitable under some scenarios, so an option is included to provide additional revenue in order to cover these costs in the form of a subsidy required by the local authority operated MRF or a higher gate fee for a commercial MRF. For the Local Authority MRF this subsidy is in addition to the avoided landfill cost. For a commercially operated MRF the model reports a gate fee that it would charge to a local authority.

2.2 Assumptions

2.2.1 Hand sorting performance

The MRF model assumes that the pickers work together in teams at 'picking stations', with each station targeting particular material streams. Separated materials are dropped by the pickers directly into separate balers for each material type.

The base case model assumes two pickers per picking station, operating either side of a wide belt with each picker covering half of the belt. There can be multiple picking stations established for each material (up to four for each material type), although it is assumed that conveyors can be arranged so that there is only one baler for each material type.

The model also assumes that each picker removes a percentage of the material that is fed through to their picking station. Pickers targeting a particular material will remove a fixed percentage of the material that is presented to them i.e. the first picking station for PET will remove, say, 50% of the PET that passes the station. The second PET picking station will remove 50% of what the first picking station leaves and so on. Diminishing returns of this type are typical in hand picking operations of this kind.

The performance of a manual hand sorting MRF is heavily dependent on the motivation of the pickers/sorters and the efficiency of the sorting environment that they are provided with at the MRF.

Nick Takel of Bowman Process Technology (Nextek project partner) provided the following commentary which was used to help establish the picking rates and separation efficiencies in the MRF models:

Hand sorting rates measured for MRF C were in the range - 70 to 100 kg/sorter/hr for bottles and mixed plastic, and up to 28 kg/sorter/hr for film. I would reduce the sort rate for mixed plastic in line with the content of bottles in the MRF C stream - depending upon the material targeted and the burden on the conveyor.

As an illustration the concentration of mixed rigids collected from the sort line in MRF A(no bottles) was around 13 kg/hr/sorter (with feed composition of 0.95% mixed rigids) and this rose to 27 kg/hr/sorter with the higher composition feed (3% to 4% mixed rigids). There are other studies that suggest rates in excess of 50 kg/hr/sorter can be achieved. The actual film sort rate at MRF A was only 2.88 kg/hr/sorter - but note that this was from the container sort line when film had already been removed at the first sort cabin, the remaining film had been reduced in size and the feed composition is normally less than 0.6% film. This rose to 5.3 kg/hr/sorter at higher levels. It is recommended that film be the first material removed from the system so that it is more readily accessed and has less opportunity to disrupt the collection of other materials.

2.2.2 Operating costs

The operating cost assumptions used in the base case model were provided to Axion by Nextek and Bowman Process Technology and are derived from data in part collected during the practical trials for this project.

Note that data which can be adjusted by users of the model is highlighted in yellow.

Table 1 MRF model base case operating assumptions – fully manual option

sorter all-in wage cost	£10.00	/hr					
Fuel for mobile plant	£1.40	/t	1.4	litres diesel/t		£ 1	/litre
Other costs	£1.00	/t					
Film baler wire cost	£3.00	/t film					
Bottle/rigid baler wire cost	£4.00	/t rigids					
Film baler power cost	£0.92	/t film	10	p/KWh	9.2	KWh/t	
Bottle/rigid baler power cost	£0.80	/t bottles	10	p/KWh	8	KWh/t	
Baseload power cost	£1.50	/hr	10	p/KWh	15	KW baseload	
Extra management cost	£30,000	/yr					
Landfill disposal cost	£58	/t					
Maintenance cost	£6,500	/yr	5%	capital cost			

The base case model for the fully manual MRF assumes that 18 manual sorters will be required.

Both the manual and semi automatic MRF models assume that the facilities operate 5 days per week on a single 8 hour shift.

In both of the MRF models landfill cost assumptions can be varied. Landfill costs are projected to increase in real terms as result of Government policy to encourage landfill diversion. Note that although plastic sent to landfill is more inert than some other household waste streams it does not attract the lower landfill disposal charges that are applied to some inert inorganic wastes. The base case assumption for both models is a total landfill cost of £58/t, comprising £40/t landfill tax plus £18/t transport and tipping cost. It is assumed that the landfill tax element alone will escalate by £8/t per year for the first three years in line with the 2009 budget statement and thereafter by £4/t per year.

No other costs in the model are inflated over time because it is assumed that real inflation will remain low for the foreseeable future and that if inflation does occur, costs (apart from landfill tax) and revenues are likely to inflate at roughly equal rates and as a result investor returns are likely to remain approximately unchanged.

Power consumption figures and power, staffing and wire costs were provided to Axion by Nextek and are based on data collected during the practical trials. Note that the cost/t of wire and power for film baling is higher than for bottles and other rigids because the bale density is lower.

The base case models assume a maintenance cost of 5% of capital cost per year. This is in line with Axion's experience of operating its own plastic recycling facility. The maintenance cost factor can be adjusted in the model.

For the local authority operated MRF, the model assumes a subsidy may be required for the plastic component of the feed material over and above avoided landfill cost. In the case of a commercial MRF the gate fee can be varied in the model to ensure that the MRF generates a positive commercial return.

Table 2 MRF model base case operating assumptions – semi-automatic option

Sorter all-in wage cost	£ 10.00	/hr					
Fuel for mobile plant	£ 1.40	/t	1.4	litres diesel/t		£ 1	/litre
Other costs	£ 1.00	/t					
Film baler wire cost	£ 3.00	/t film					
Bottle/rigid baler wire cost	£ 4.00	/t rigids					
Film baler power cost	£ 0.92	/t film	10	p/KWh	9.2	KWh/t	
Bottle/rigid baler power cost	£ 0.88	/t bottles	10	p/KWh	8	KWh/t	
Base load + NIR power cost	£ 3.70	/hr	10	p/KWh	37	KW baseload	
Extra management cost	£ 30,000	/yr					
Landfill cost	£ 58	/t					
Maintenance cost	£ 29,000	/yr	5%	capital cost			

The base case for the semi-automatic MRF assumes six sorters will be required, working 5 days per week, 8 hours per day.

2.2.3 Price assumptions

Axion estimated the following ex works prices for the baled plastic product fractions from the MRFs in mid 2009 following extensive consultation with leading players in the UK plastic recycling sector:

- Clear PET bottles £200/t
- Natural HDPE bottles £250/t
- Mixed rigid plastics including PET and HDPE bottles £100/t
- Mixed rigid plastics excl PET and HDPE bottles £40/t
- Mixed household packaging films £0/t

These are the prices used in the base case models and do not take into account any potential benefit from packaging recycling notes (PRNs) because MRFs cannot normally claim PRNs. For this project PRN revenue is shown in the PRF and reprocessing facility model.

Information on recoverd prices from WRAP's Materials Pricing Report in May 2009 gave the following ex works price indications:

- Clear PET bottles £185-205/t
- Natural HDPE bottles £250-265/t
- Mixed bottles (including PET and HDPE) £130-£150/t

However, WRAP's Materials Pricing Report does not cover values for baled mixed rigid plastics excluding PET and HDPE however other recent market enquiries by Axion indicate prices in the range £20-50/t for this material and £0-10/t for baled film. These lower grade fractions have not increased in price to the same extent as the clear PET and natural HDPE materials.

2.2.4 Capital costs

The base case capital cost for the fully manual MRF option is £130,000. This total comprises £10,000 for modifications to the existing picking stations and £120,000 for balers for the four product streams (PET bottles, HDPE bottles, mixed rigid plastics and plastic films).

The base case capital cost for the semi-automatic MRF using NIR sorting technology is £580,000, which includes the costs of three NIR sorters and four balers (as detailed above), plus the associated picking station changes and conveyors, etc.

The base case capital cost for the fully automated MRF processing a mixed recyclable feed that excludes glass and paper is £160,000. This total comprises £40,000 for conveyors and control systems, £60,000 for a ballistic film separator £30,000 for a film baler and £30,000 for a baler for mixed rigid containers including bottles.

2.3 Cash flow projection – manual MRF

Table 3 Ten year cash flow forecast for the base case manual MRF

Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Base Calculations											
Operating Parameters (tonnes)											
% maximum throughput achieved		70%	80%	95%	100%	100%	100%	100%	100%	100%	100%
Total mixed plastic throughput		**1,488**	**1,701**	**2,020**	**2,126**	**2,126**	**2,126**	**2,126**	**2,126**	**2,126**	**2,126**
PET recovered		**422**	**483**	**573**	**603**	**603**	**603**	**603**	**603**	**603**	**603**
HDPE recovered		**126**	**145**	**172**	**181**	**181**	**181**	**181**	**181**	**181**	**181**
Other Rigid Plastics		**178**	**204**	**242**	**255**	**255**	**255**	**255**	**255**	**255**	**255**
Films recovered		**235**	**268**	**319**	**336**	**336**	**336**	**336**	**336**	**336**	**336**
Waste to landfill		**526**	**601**	**714**	**751**	**751**	**751**	**751**	**751**	**751**	**751**
mixed plastic landfill diversion		65%	65%	65%	65%	65%	65%	65%	65%	65%	65%
Useful plastic output from mixed plastic input		**962**	**1,100**	**1,306**	**1,375**	**1,375**	**1,375**	**1,375**	**1,375**	**1,375**	**1,375**
Unit prices											
Mixed plastic separation charge to local authority (premium over landfill		£63	£63	£63	£63	£63	£63	£63	£63	£63	£63
Equivalent commercial MRF gate fee		£121	£129	£137	£145	£149	£153	£157	£161	£165	£169
PET		£200	£200	£200	£200	£200	£200	£200	£200	£200	£200
HDPE		£250	£250	£250	£250	£250	£250	£250	£250	£250	£250
Other Rigid Plastics		£40	£40	£40	£40	£40	£40	£40	£40	£40	£40
Films		£0	£0	£0	£0	£0	£0	£0	£0	£0	£0
MRF landfill cost assumption											
Landfill tax escalator			£8	£8	£8	£4	£4	£4	£4	£4	£4
Tax element		£40	£48	£56	£64	£68	£72	£76	£80	£84	£88
landfill void element		£10	£10	£10	£10	£10	£10	£10	£10	£10	£10
transport element		£8	£8	£8	£8	£8	£8	£8	£8	£8	£8
MRF landfill cost assumption		£58	£66	£74	£82	£86	£90	£94	£98	£102	£106
Incremental income from additional mixed plastic throughput											
Gate Fee		180,059	219,388	276,679	308,248	316,752	325,255	333,758	342,262	350,765	359,269
PET		78,003	78,003	78,003	78,003	78,003	78,003	78,003	78,003	78,003	78,003
HDPE		29,208	29,208	29,208	29,208	29,208	29,208	29,208	29,208	29,208	29,208
Other Rigid Plastics		6,594	6,594	6,594	6,594	6,594	6,594	6,594	6,594	6,594	6,594
Films		0	0	0	0	0	0	0	0	0	0
Total Product Sales		113,805	113,805	113,805	113,805	113,805	113,805	113,805	113,805	113,805	113,805
Total income		**293,864**	**446,998**	**504,289**	**535,858**	**544,362**	**552,865**	**561,368**	**569,872**	**578,375**	**586,879**
income/te recovered (inc net landfill diversion)		£ 274	£ 370	£ 346	£ 345	£ 349	£ 353	£ 357	£ 361	£ 365	£ 369
Incremental operating costs for new equipment											
sorter all-in wage cost		257,040	293,760	348,840	367,200	367,200	367,200	367,200	367,200	367,200	367,200
Fuel for mobile plant		2,083	2,381	2,827	2,976	2,976	2,976	2,976	2,976	2,976	2,976
Other costs		1,488	1,701	2,020	2,126	2,126	2,126	2,126	2,126	2,126	2,126
Film baler wire cost		705	805	957	1,007	1,007	1,007	1,007	1,007	1,007	1,007
Bottle/rigid baler wire cost		2,909	3,324	3,948	4,156	4,156	4,156	4,156	4,156	4,156	4,156
Film baler power cost		216	247	293	309	309	309	309	309	309	309
Bottle/rigid baler power cost		582	665	790	831	831	831	831	831	831	831
Baseload op power cost		1,499	1,714	2,035	2,142	2,142	2,142	2,142	2,142	2,142	2,142
Extra management cost		30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000
Landfill disposal cost		30,505	39,671	52,820	61,611	64,616	67,621	70,627	73,632	76,637	79,643
Maintenance cost			6,500	6,500	6,500	6,500	6,500	6,500	6,500	6,500	6,500
Lease cost (£20/month/'000 over 5 years)		31,200	31,200	31,200	31,200	31,200	6,240	6,240	6,240	6,240	6,240
Total costs		**358,227**	**411,968**	**482,229**	**510,057**	**513,062**	**491,108**	**494,113**	**497,118**	**500,124**	**503,129**
Operating Cash Flow		**-64,363**	**35,030**	**22,061**	**25,801**	**31,299**	**61,757**	**67,255**	**72,753**	**78,251**	**83,749**
Processing cost/te recovered (excludes landfill)		£ 341	£ 339	£ 329	£ 326	£ 326	£ 308	£ 308	£ 308	£ 308	£ 308
Margin/te recovered		-£67	£32	£17	£19	£23	£45	£49	£53	£57	£61
Capital Expenditure											
Equipment, buildings and working cap funded by equity	0	0									
Plant (funded by Lease)											
Picking station mods	10,000										
Baler for rigids	30,000										
Baler for film	30,000										
Balers for PET and HDPE	60,000										
	130,000	0	0	0	0	0	0	0	0	0	0
Net Cash Flow	-130,000	-64,363	35,030	22,061	25,801	31,299	61,757	67,255	72,753	78,251	83,749
Cumulative Cash Flow	-130,000	-194,363	-159,333	-137,273	-111,471	-80,172	-18,414	48,841	121,595	199,846	283,595
10 yr IRR (Internal Rate of Return)	15%										
NPV (Net Present Value)	4,050	15%	Discount rate								

2.4 Cash flow projection semi-automatic MRF

Table 4 Ten year cash flow forecast for the base case semi-automatic MRF

Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Base Calculations											
Operating Parameters (tonnes)											
% maximum throughput achieved		70%	80%	95%	100%	100%	100%	100%	100%	100%	100%
Total mixed plastic throughput		**1,488**	**1,701**	**2,020**	**2,126**	**2,126**	**2,126**	**2,126**	**2,126**	**2,126**	**2,126**
PET recovered		**434**	**496**	**589**	**620**	**620**	**620**	**620**	**620**	**620**	**620**
HDPE recovered		**228**	**260**	**309**	**325**	**325**	**325**	**325**	**325**	**325**	**325**
Other Rigid Plastics		**297**	**339**	**403**	**424**	**424**	**424**	**424**	**424**	**424**	**424**
Films recovered		**235**	**268**	**319**	**336**	**336**	**336**	**336**	**336**	**336**	**336**
Waste to landfill		**294**	**336**	**400**	**421**	**421**	**421**	**421**	**421**	**421**	**421**
mixed plastic landfill diversion		80%	80%	80%	80%	80%	80%	80%	80%	80%	80%
Useful plastic output from mixed plastic input		**1,194**	**1,364**	**1,620**	**1,705**	**1,705**	**1,705**	**1,705**	**1,705**	**1,705**	**1,705**
Unit prices (£/te)											
Equivalent commercial MRF gate fee		£32	£40	£48	£56	£60	£64	£68	£72	£76	£80
PET		£200	£200	£200	£200	£200	£200	£200	£200	£200	£200
HDPE		£250	£250	£250	£250	£250	£250	£250	£250	£250	£250
Other Rigid Plastics		£40	£40	£40	£40	£40	£40	£40	£40	£40	£40
Films		£0	£0	£0	£0	£0	£0	£0	£0	£0	£0
MRF landfill cost assumption											
Landfill tax escalator			£8	£8	£8	£4	£4	£4	£4	£4	£4
Tax element		£40	£48	£56	£64	£68	£72	£76	£80	£84	£88
landfill void element		£10	£10	£10	£10	£10	£10	£10	£10	£10	£10
transport element		£8	£8	£8	£8	£8	£8	£8	£8	£8	£8
MRF landfill cost assumption		£58	£66	£74	£82	£86	£90	£94	£98	£102	£106
Incremental income from additional mixed plastic throughput											
Gate Fee		47,619	68,027	96,939	119,048	127,551	136,054	144,558	153,061	161,565	170,068
PET		99,537	99,537	99,537	99,537	99,537	99,537	99,537	99,537	99,537	99,537
HDPE		65,209	65,209	65,209	65,209	65,209	65,209	65,209	65,209	65,209	65,209
Other Rigid Plastics		13,605	13,605	13,605	13,605	13,605	13,605	13,605	13,605	13,605	13,605
Films		0	0	0	0	0	0	0	0	0	0
Total Product Sales		178,351	178,351	178,351	178,351	178,351	178,351	178,351	178,351	178,351	178,351
Total income		**225,970**	**424,729**	**453,641**	**475,750**	**484,253**	**492,757**	**501,260**	**509,763**	**518,267**	**526,770**
income/te recovered (inc net landfill diversion)		£ 175	£ 295	£ 262	£ 259	£ 263	£ 267	£ 271	£ 275	£ 279	£ 283
Incremental operating costs for new equipment											
sorter all-in wage cost		85,680	97,920	116,280	122,400	122,400	122,400	122,400	122,400	122,400	122,400
Fuel for mobile plant		2,083	2,381	2,827	2,976	2,976	2,976	2,976	2,976	2,976	2,976
Other costs		1,488	1,701	2,020	2,126	2,126	2,126	2,126	2,126	2,126	2,126
Film baler wire cost		705	805	957	1,007	1,007	1,007	1,007	1,007	1,007	1,007
Bottle/rigid baler wire cost		3,835	4,383	5,205	5,479	5,479	5,479	5,479	5,479	5,479	5,479
Film baler power cost		216	247	293	309	309	309	309	309	309	309
Bottle/rigid baler power cost		844	964	1,145	1,205	1,205	1,205	1,205	1,205	1,205	1,205
Baseload + NIR op power cost		3,699	4,227	5,019	5,284	5,284	5,284	5,284	5,284	5,284	5,284
Extra management cost		30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000
Landfill disposal cost		17,077	22,208	29,569	34,490	36,172	37,854	39,537	41,219	42,902	44,584
Maintenance cost			29,000	29,000	29,000	29,000	29,000	29,000	29,000	29,000	29,000
Lease cost (£20/month/'000 over 5 years)		139,200	139,200	139,200	139,200	139,200	27,840	27,840	27,840	27,840	27,840
Total costs		**284,826**	**333,036**	**361,514**	**373,475**	**375,157**	**265,480**	**267,162**	**268,844**	**270,527**	**272,209**
Operating Cash Flow		**-58,856**	**91,693**	**92,127**	**102,275**	**109,096**	**227,277**	**234,098**	**240,919**	**247,740**	**254,561**
Processing cost/te recovered (excludes landfill)		£ 224	£ 228	£ 205	£ 199	£ 199	£ 133	£ 133	£ 133	£ 133	£ 133
Margin/te recovered		-£49	£67	£57	£60	£64	£133	£137	£141	£145	£149
Capital Expenditure											
Equipment, buildings and working cap funded by equity	0	0									
Plant (funded by Lease)											
Picking station mods	10,000										
NIR sorters for 3 materials	300,000										
Conveyors and feeders	150,000										
Baler for rigids	30,000										
Baler for film	30,000										
Balers for PET and HDPE	60,000										
	580,000	0	0	0	0	0	0	0	0	0	0
Net Cash Flow	-580,000	-58,856	91,693	92,127	102,275	109,096	227,277	234,098	240,919	247,740	254,561
Cumulative Cash Flow	-580,000	-638,856	-547,162	-455,036	-352,761	-243,664	-16,387	217,711	458,630	706,370	960,931
10 yr IRR (Internal Rate of Return)	15%										
NPV (Net Present Value)	9,813	15% Discount rate									

2.5 Cash flow projection fully automated MRF

Table 5 Ten year cash flow forecast for the fully automated MRF processing a feed that excludes paper and card

Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Base Calculations										
Operating Parameters (tonnes)										
% maximum throughput achieved		70%	80%	95%	100%	100%	100%	100%	100%	100%
Total mixed plastic throughput		**1,523**	**1,741**	**2,067**	**2,176**	**2,176**	**2,176**	**2,176**	**2,176**	**2,176**
PET recovered		**391**	**447**	**530**	**558**	**558**	**558**	**558**	**558**	**558**
HDPE recovered		**283**	**324**	**384**	**405**	**405**	**405**	**405**	**405**	**405**
Other Rigid Plastics		**372**	**425**	**505**	**531**	**531**	**531**	**531**	**531**	**531**
Films recovered		**139**	**149**	**177**	**186**	**186**	**186**	**186**	**186**	**186**
Waste to landfill		**347**	**397**	**472**	**496**	**496**	**496**	**496**	**496**	**496**
mixed plastic landfill diversion		77%	77%	77%	77%	77%	77%	77%	77%	77%
Useful plastic output from mixed plastic input		**1,176**	**1,344**	**1,596**	**1,680**	**1,680**	**1,680**	**1,680**	**1,680**	**1,680**
Unit prices										
Commercial MRF gate fee (negative = positive price for material)		-£37	-£29	-£21	-£13	-£9	-£5	-£1	£3	£7
PET		£100	£100	£100	£100	£100	£100	£100	£100	£100
HDPE		£100	£100	£100	£100	£100	£100	£100	£100	£100
Other Rigid Plastics		£100	£100	£100	£100	£100	£100	£100	£100	£100
Films		£0	£0	£0	£0	£0	£0	£0	£0	£0
MRF landfill cost assumption										
Landfill tax escalator			£8	£8	£8	£4	£4	£4	£4	£4
Tax element		£40	£48	£56	£64	£68	£72	£76	£80	£84
landfill void element		£10	£10	£10	£10	£10	£10	£10	£10	£10
transport element		£8	£8	£8	£8	£8	£8	£8	£8	£8
MRF landfill cost assumption		£58	£66	£74	£82	£86	£90	£94	£98	£102
Incremental income from additional mixed plastic throughput										
Gate Fee		-56,366	-50,490	-43,417	-28,292	-19,586	-10,881	-2,176	6,529	15,234
PET		43,085	43,085	43,085	43,085	43,085	43,085	43,085	43,085	43,085
HDPE		31,229	31,229	31,229	31,229	31,229	31,229	31,229	31,229	31,229
Other Rigid Plastics		41,001	41,001	41,001	41,001	41,001	41,001	41,001	41,001	41,001
Films		0	0	0	0	0	0	0	0	0
Total Product Sales		115,315	115,315	115,315	115,315	115,315	115,315	115,315	115,315	115,315
Total income		**58,950**	**180,141**	**187,214**	**202,339**	**211,044**	**219,749**	**228,454**	**237,159**	**245,864**
income/te recovered (inc net landfill diversion)		£ 33	£ 115	£ 95	£ 96	£ 100	£ 104	£ 108	£ 112	£ 116
Incremental operating costs for new equipment										
sorter all-in wage cost		28,603	32,689	38,818	40,861	40,861	40,861	40,861	40,861	40,861
Fuel for mobile plant		2,133	2,437	2,894	3,047	3,047	3,047	3,047	3,047	3,047
Other costs		1,523	1,741	2,067	2,176	2,176	2,176	2,176	2,176	2,176
Film baler wire cost		391	447	530	558	558	558	558	558	558
Bottle/rigid baler wire cost		4,183	4,780	5,677	5,975	5,975	5,975	5,975	5,975	5,975
Film baler power cost		120	137	163	171	171	171	171	171	171
Bottle/rigid baler power cost		837	956	1,135	1,195	1,195	1,195	1,195	1,195	1,195
Baseload op power cost		1,499	1,714	2,035	2,142	2,142	2,142	2,142	2,142	2,142
Extra management cost		30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000
Landfill disposal cost		20,152	26,207	34,893	40,701	42,686	44,672	46,657	48,642	50,628
Maintenance cost			8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000
Lease cost (£20/month/'000 over 5 years)		38,400	38,400	38,400	38,400	38,400	7,680	7,680	7,680	7,680
Total costs		**127,840**	**147,508**	**164,613**	**173,227**	**175,212**	**146,478**	**148,463**	**150,449**	**152,434**
Operating Cash Flow		**-68,890**	**32,633**	**22,601**	**29,112**	**35,832**	**73,271**	**79,991**	**86,711**	**93,431**
Processing cost/te recovered (excludes landfill)		£ 92	£ 90	£ 81	£ 79	£ 79	£ 61	£ 61	£ 61	£ 61
Margin/te recovered		-£59	£24	£14	£17	£21	£44	£48	£52	£56
Capital Expenditure										
Equipment, buildings and working cap funded by equity	0	0								
Plant (funded by Lease)										
Conveyor mods	40,000									
Ballistic separator	60,000									
Baler for film	30,000									
Balers for mixed rigids	30,000									
	160,000	0	0	0	0	0	0	0	0	0
Net Cash Flow	-160,000	-68,890	32,633	22,601	29,112	35,832	73,271	79,991	86,711	93,431
Cumulative Cash Flow	-160,000	-228,890	-196,258	-173,657	-144,545	-108,713	-35,442	44,549	131,260	224,691
10 yr IRR (Internal Rate of Return)	15%									
NPV (Net Present Value)	-4,501	15%	Discount rate							

2.6 Key data and analysis

The projections from the financial models indicate that a manual MRF handling paper, cardboard, metals and plastics with a nominal capacity of 10t/hr and an actual throughput of approximately 7t/hr, will require a subsidy of around £9.00/t of all dry recyclables if a local authority operated MRF over the avoided landfill charge of £58/t in order to justify investment in a manual picking operation for a mixed plastics stream. This equates to a gate fee of £121/t for the additional mixed plastics delivered to a commercial MRF.

The projections for the semi-automated MRF, with the same capacity and feed mix as the fully manual operation, show that it should be able to provide positive financial returns on an investment of £580,000 in mixed plastic processing with no subsidy if a local authority operated MRF or a gate fee of around £32/t for the additional mixed plastic tonnage if a commercial MRF.

The fully automated MRF processing a feed that excludes paper and card should be able to provide very attractive financial returns on an investment of £160,000 in mixed plastic processing with no subsidy if a local authority operated MRF and may even be able to pay a positive price for the additional mixed plastic tonnage if a commercial MRF .

In each of the above cases the gate fee estimates are based on the assumption that the minimum acceptable project IRR for the incremental investment in a mixed plastic sorting facility is 15%.

2.7 Sensitivity analysis

2.7.1 Choice of scenarios

Several sensitivity scenarios were identified through discussion with WRAP and Nextek. These have been applied to the MRF models as follows:

- tonnage throughput of the MRFs;
- staff salaries;
- single sorter separation efficiency;
- price variation for the recovered fractions (plastic films, mixed rigid plastics, HDPE bottles and PET bottles); and
- choice of fractions to be recovered by the MRF sorting process:
    - Films and a single mixed rigid fraction including PET and HDPE bottles
    - Films, PET bottles, HDPE bottles and mixed rigids

In each sensitivity scenario the gate fee charged by the MRF was adjusted in order to produce a project IRR of 15% for the incremental investment in the plastic sorting facility.

2.7.2 Sensitivity results

The results of the sensitivity analysis on the MRF models are discussed in the following sub-sections and summarised in section 2.8:

2.7.2.1 Tonnage throughput

For the fully manual MRF, the sensitivity analysis shows there is no major advantage in building a manual picking line with a higher capacity in terms of the level of subsidy required by a local authority operated MRF over avoided landfill cost, or a gate fee for a commercial MRF to justify the investment. A 20t/hr manual MRF operated by a local authority requires a gate fee premium of around £6/t over avoided landfill cost for all dry recyclables compared to a subsidy of £9.00/t for a 10t/hr MRF in addition to avoided landfill cost. For a commercial MRF that is a gate fee of £100/t of mixed plastics and bottles compared with £121 for a 10/t hr operation.

Returns for the semi-automated MRF are significantly better if the scale of the MRF is increased from a capacity of 10t/hr to 20t/hr of mixed dry recyclables. The gate fee is reduced from £32/t to the point where a commercial MRF should be able to pay a significant positive price for the additional mixed plastic feed. This is because it is easier to justify the relatively high capital cost of the near infra red sorting machines for PET, HDPE and mixed rigids when their cost is spread over a larger throughput.

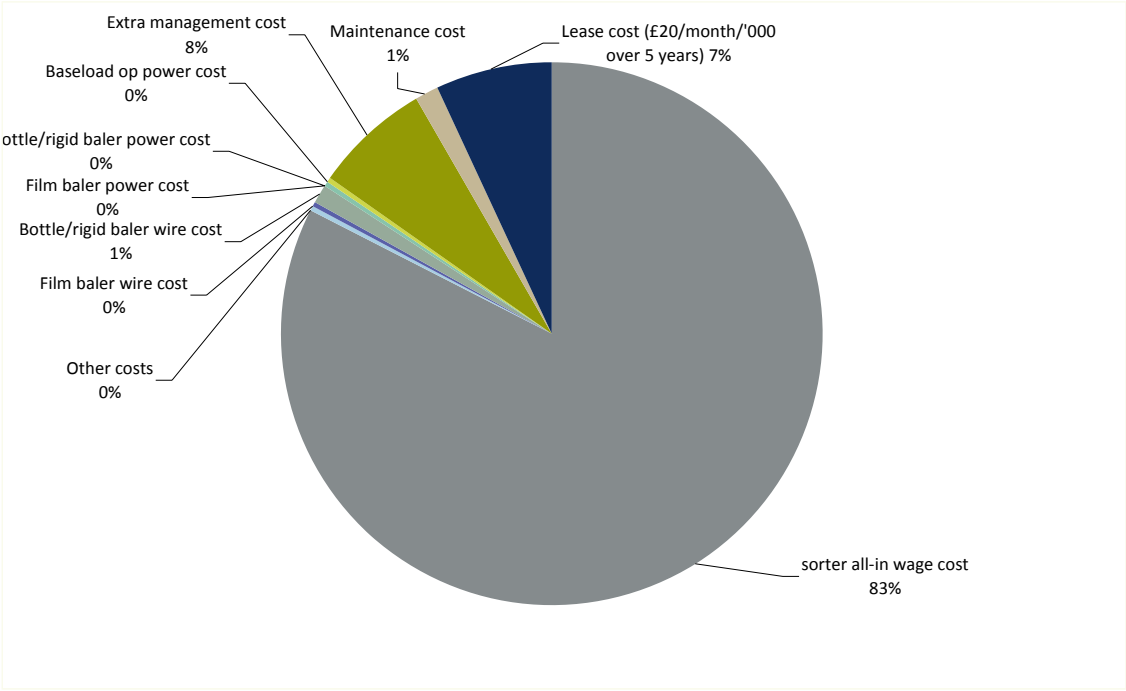
2.7.2.2 Staff salaries

Variations in levels of staff salaries have also been modelled for the manual and semi-automatic MRF options.

The base case manual MRF model assumes an all-in cost for employing the picking staff of £10/hr per person.

Staff costs are the major component of the cost base for the manual MRF as shown below. As a result the financial returns are sensitive to changes in staff productivity or salary.

Figure 8 Breakdown of operating costs for the base case manual MRF showing high proportion of staff costs

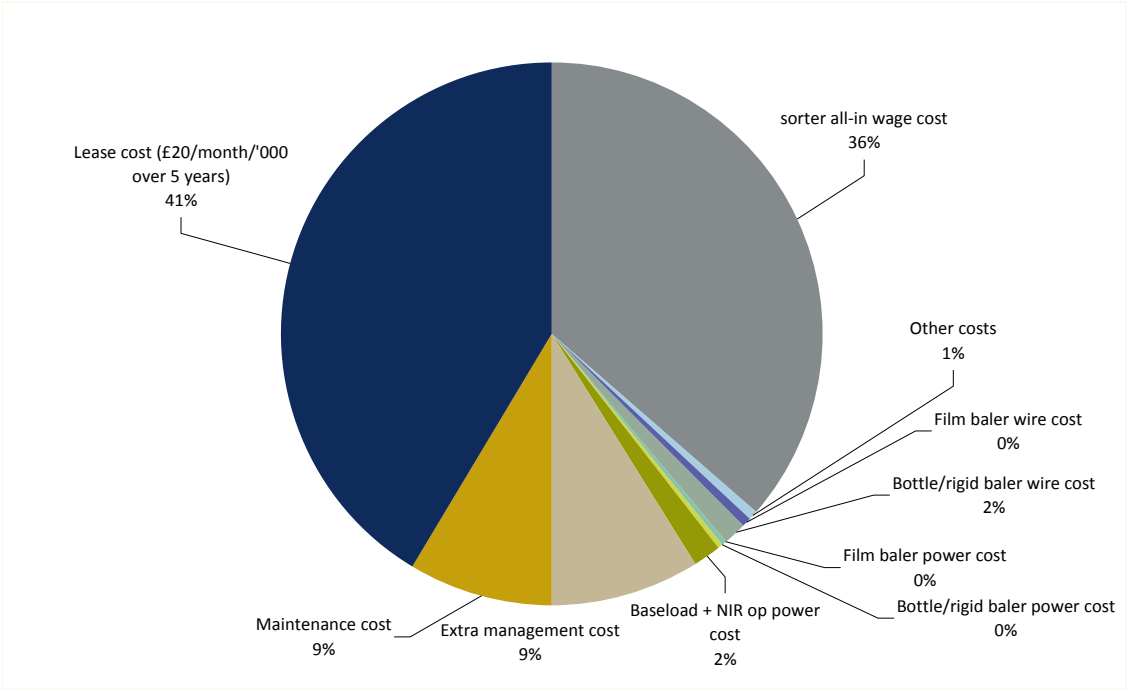


The sensitivity analysis shows that, for a manual MRF, reducing staff costs to £8/hr per person will reduce the subsidy required for a local authority operated MRF over avoided landfill cost that is required for processing a mixed plastic waste stream from £9.00/t to £4.00/t of all dry recyclables. That is a reduction in the gate fee for a commercial MRF from £121/t to £88/t for the additional plastic feed into the MRF.

In comparison increasing staff costs to £15/hr per person results in an increase in the subsidy required for a local authority operated MRF over avoided landfill cost to £29/t of all dry recyclables into the MRF. That is an increase in the gate fee for a commercial MRF from £121/t to £209/t for the additional plastic feed into the MRF.

The semi-automatic MRF is relatively insensitive to changes in wage costs because other costs are more important in this case as shown below:

Figure 9 Breakdown of operating costs for the base case semi-automatic MRF showing low proportion of staff costs compared to equipment-related costs



Increasing staff wage costs for the plastic film pickers from £10 to £15/hr increases the gate fee required for the additional mixed plastic feed from £32/t to £61/t for a commercial MRF. This is still a smaller wage-related effect than in the case of the manual MRF option.

2.7.2.3 *Single sorter separation efficiency*

Variations in the single sorter separation efficiency have been modelled in order to analyse the impact this has on the financial sustainability of the MRF operations.

The base case manual MRF model assumes separation efficiencies for each material stream as follows:

- Films 30% per picking station with 2 sorters per station and 3 picking stations
- PET 50% per picking station with 2 sorters per station and 3 picking stations
- HDPE 50% per picking station with 2 sorters per station and 1 picking station
- Rigids 30% per picking station with 2 sorters per station and 2 picking stations

A total of 18 sorting staff.

These assumptions result in the following overall separation efficiencies and picking rates for the sorters:

- Films 66% overall 27 Kg/hr per sorter
- PET 88% overall 48 Kg/hr per sorter
- HDPE 50% overall 44 Kg/hr per sorter
- Rigids 51% overall 31 Kg/hr per sorter

Note that these efficiencies were measured by Nextek, Valpak and Bowman Process Technology in their practical trials at the MRFs.

Increasing individual sorter separation efficiency by 20% for each sorter reduces the number of sorters and picking stations required but also increases the amount of material that each sorter must handle and sort with the following results:

- Films 50% per picking station with 4 sorters per station and 1 picking station
- PET 70% per picking station with 2 sorters per station and 2 picking stations
- HDPE 70% per picking station with 2 sorters per station and 1 picking station
- Rigids 50% per picking station with 2 sorters per station and 1 picking station

A total of 12 sorting staff.

These assumptions result in the following overall separation efficiencies and picking rates for the sorters:

- Films 50% overall 31 Kg/hr per sorter
- PET 91% overall 77 Kg/hr per sorter
- HDPE 70% overall 62 Kg/hr per sorter
- Rigids 50% overall 61 Kg/hr per sorter

This scenario makes the investment in mixed plastic and bottle sorting much more attractive as no subsidy is required for a local authority operated MRF (compared to £9.00/t of all dry recyclables for the base case scenario). That is a reduction in the gate fee for a commercial MRF from £121/t to £9/t of mixed plastics and bottles. However, based on the trials conducted by Bowman Process Technology for this project, achieving such high sorting efficiencies is likely to be very difficult to achieve consistently in practice.

This sensitivity was only applied to the fully manual MRF scenario because the sorting efficiencies of automated NIR sorters are much higher and are well proven.

In the model it has been assumed that the automated NIR sorters will achieve 90% separation efficiency for PET and HDPE bottles and 85% when ejecting all other rigids (because some material will be black and will not be detected by the sorters).

Trials by Axion in the past have indicated higher separation efficiencies than this for NIR sorters when used for packaging. However, increasing the efficiency further to say 95% has little effect on the commercial returns for the semi-automatic MRF model.

2.7.2.4 Price variation for recovered fractions

The price of baled plastics varies significantly in response to world supply and demand.

Increasing the prices for baled PET from £200/t to £220t, baled HDPE from £250/t to £270/t and for baled rigid plastics from £40/t to £50/t in the manual MRF scenario for a local authority operated MRF reduces the gate fee premium required over avoided landfill cost from £9.00/t of all dry recyclables to £7.50/t. For a commercial MRF the gate fee per tonne of additional mixed plastics and bottles in the feed to the MRF would drop from £121/t to £111/t. Note the assumption is that these price increases are sustained for the full ten year project period.

Improving sorter efficiency (and therefore reducing the number of sorters) has a bigger effect on returns than the likely variation in selling price for the baled product in the case of the manual MRF.

The same price increases for the base case semi-automatic MRF model reduce the gate fee that a commercial MRF could pay from £32/t to £17/t of additional mixed plastic feed.

2.7.2.5 Choice of recovered fractions

The base case models assume that separate film, HDPE, PET and mixed rigid fractions are recovered. It may be better to do this at the mixed plastics PRF and reprocessing plant in order to benefit from economies of scale and use automated sorting.

Separating only films and PET in the semi-automatic MRF

It is possible to cut back the semi-automatic MRF so that it separates only films (manually as in the base case) and the largest volume fraction of useful bottle and non-bottle plastic (clear PET). A second NIR sorter is required to separate the HDPE and other mixed rigid fractions from the residue fraction after NIR separation of the clear PET fraction.

It is assumed in this scenario that the baled PET fraction can be sold at £200/te and that the baled mixed HDPE and other rigids fraction can be sold at £70/t.

This compares with price assumptions for the mixed rigid fraction of £40/t for mixed rigids excluding PET and HDPE in the base case or £100/t for mixed rigids if both natural HDPE and clear PET are included.

This scenario looks attractive at the base case nominal throughput of 10t/hr for the MRF. It does not require a gate fee premium and a commercial MRF may be able to pay a small positive price for the additional mixed plastic feed.

There is further potential upside in that it may be possible to re-run the mixed rigid fraction over the single NIR sorter at night or weekends in order to positively pick more valuable HDPE and PP fractions.

Separating only films and mixed rigids in the semi-automatic MRF

It is also possible to cut back the semi-automatic MRF even further so that it separates only films (manually as in the base case) and uses a single NIR sorter to separate all mixed rigid fractions together, including natural HDPE and clear PET bottles and other rigids.

It is assumed in this scenario that the baled mixed rigids fraction (including clear PET and natural HDPE) can be sold at £100/te.

This scenario looks equally attractive at the base case nominal throughput of 10t/hr for the MRF. A commercial MRF would require a relatively small gate fee of £9/t for the additional mixed plastic and bottle feed.

2.8 Summary of MRF sensitivity analysis results

Table 6 Summary of MRF sensitivity analysis results

Scenario	MRF model	Sensitivity Value	Subsidy required by LA operated MRF over avoided landfill cost to achieve 15% IRR (£/t mixed plastics)	Subsidy required by LA operated MRF over avoided landfill cost to achieve 15% IRR (£/t all dry recyclables incl mixed plastics)	Gate fee for a commercial MRF to achieve 15% IRR (£/t mixed plastics)
Base case	Manual	-	£63/t	£9.00/t	£121/t
	Semi-automatic	-	nil	nil	£32/t
No paper and card in feed	Fully automated	-	nil	nil	-£37/t
Rated tonnage throughput (Base case 10t/hr)	Manual	20t/hr	£42/t	£6/t	£100/t
	Semi-automatic	20t/hr	nil	nil	-£38/t
Staff wages (base case £10/hr)	Manual	£8/hr/person	£30/t	£4.00/t	£88/t
		£15/hr/person	£151/t	£29/t	£209/t
	Semi-automatic	£15/hr/person	£3/t	£0.5/t	£61/t
Single sorter separation efficiency	Manual	+20%	nil	nil	£9/t
Price variation for recovered fractions	Manual	£220/t PET £270/t HDPE £50/t rigids	£53/t	£7.50/t	£111/t
	Semi-automatic	£220/t PET £270/t HDPE £50/t rigids	nil	nil	£17/t

Scenario	MRF model	Sensitivity Value	Subsidy required by LA operated MRF over avoided landfill cost to achieve 15% IRR (£/t mixed plastics)	Subsidy required by LA operated MRF over avoided landfill cost to achieve 15% IRR (£/t all dry recyclables incl mixed plastics)	Gate fee for a commercial MRF to achieve 15% IRR (£/t mixed plastics)
Choice of recovered fractions	Semi-automatic	Film, and clear PET only picked, Baled clear PET sold for £200/t All other rigids and bottles including HDPE recovered together and sold for £70/t	nil	nil	nil or small positive price for additional mixed plastic feed
	Semi-automatic	Film, and All other rigids and bottles including PET and HDPE recovered together and sold for £100/t	nil	nil	£9/t
	Semi-automatic	Film, and All other rigids and bottles including PET and HDPE recovered together and sold at reduced price of £50/t	£5/t	£0.70/t	£63/t

Note: The model shows that the MRF is not profitable under some scenarios, so an option is included to provide additional revenue in order to cover these costs in the form of a subsidy required by the local authority or a higher gate fee for a commercial MRF. For the local authority MRF this subsidy is in addition to the avoided landfill cost. For a commercially operated MRF the model reports a gate fee that it would charge to a local authority.

2.9 Conclusions: MRF modelling

The conclusions for the MRF element of the financial assessment of an integrated mixed plastics waste management solution are:

- The assumptions used in the models attached to this report lead us to conclude that the base case scenarios modelled in this report look attractive.
- If it is possible to exclude paper and card from the mixed dry recyclable collection by collecting them separately at kerbside then it should be possible to automate separation of films and mixed rigid plastics completely. This option gives very attractive returns. This should also improve quality of the paper/ card stream and may also improve the quality of the glass stream as the mixed plastics should help to 'cushion' the glass in transit and minimise breakages. Measurements by Nextek indicate that paper and card account for over 50% by weight of the household recyclable stream so splitting the paper/card stream from other dry recyclables when mixed plastic collections are introduced should result in a roughly equal split of collection weights between paper/card and other dry recyclables (including glass).

- A semi-automated MRF which uses two near infra red sorters, one to separate PET containers and one to separate all other rigid plastics and bottles into a single stream of baled mixed rigid plastics for further processing by others is the most attractive option when the feed to the MRF includes paper and card, especially at higher throughputs. This may not require a gate fee for the additional mixed plastic and bottles in the feed.
- A semi-automated MRF which uses a single near infra red sorter to separate all rigid plastics and bottles into a single stream of baled mixed rigid plastics for further processing by others is also an attractive option.

- A fully manual MRF operating at a nominal throughput of 10t/hr will have low incremental capital cost but will require a subsidy of about £9.00/t across all dry recyclables over avoided landfill cost for a local authority operated MRF to make it financially viable. This equates to a gate fee of about £120/t for the additional mixed plastic feed for a commercial MRF.
- Increasing the scale of the manual MRF does not improve the commercial viability of the manual picking option significantly;
- Likely variations in selling price for the product have less impact on commercial viability than sorter labour cost, especially for the all-manual options; and
- Development of an automated technique to replace manual film sorting to separate plastic films from paper and card should pay back quickly.

3.0 Mixed plastics PRF and reprocessing generic model

3.1 Overview of model

The mixed plastics integrated PRF sorting and reprocessing model is a full cash flow, profit and loss and balance sheet projection model, which projects the incremental cash flows resulting from investment in a new stand-alone integrated PRF and plastics reprocessing facility to process a mixed plastics waste stream from household kerbside recyclable collections.

It is assumed that the waste collection authority will introduce collection of a full range of mixed plastics to an existing kerbside recycling service, which will already be collecting paper, cardboard, metals and possibly glass.

It is assumed that third party MRFs will separate out the mixed films fraction from the mixed dry recyclables first and then separate all the other mixed rigid plastic containers at some stage after separation of the paper, cardboard, glass and metals streams. Both the film and the mixed rigid plastic fractions (including bottles) will be baled at the MRF and supplied to the mixed plastics reprocessing plant by road transport.

The financial model projects revenues and costs for the project over a 10 year period, comprising two years of plant construction and capacity build up and eight years of steady state operation.

It makes estimates for the internal rate of return (IRR), net present value (NPV) over a ten year timescale and the equity investment return over a shorter seven year timescale. A shorter time scale is used for the equity investment returns because early equity investors are assumed to wish to exit within a shorter time period than 10 years.

The model shows that the integrated mixed plastics PRF and reprocessing plant is profitable under the base case scenario – which is based on costs, yields and other operating parameters provided by Nextek.

The sensitivity analysis for the integrated PRF and reprocessing plant also modelled scenarios where the scope of the integrated facility was reduced to eliminate sections of the reprocessing plant or where sections of the PRF and reprocessing plant are added to existing facilities.

3.2 Assumptions

The assumptions used to create the plastics reprocessing facility model are set out in the following sections.

3.2.1 Financing assumptions

The model assumes that equity investors make their returns partly through a dividend distribution of 50% of post tax profit once the business is profitable and partly through sale of their shares after seven years at a multiple of five times post tax profit in that year.

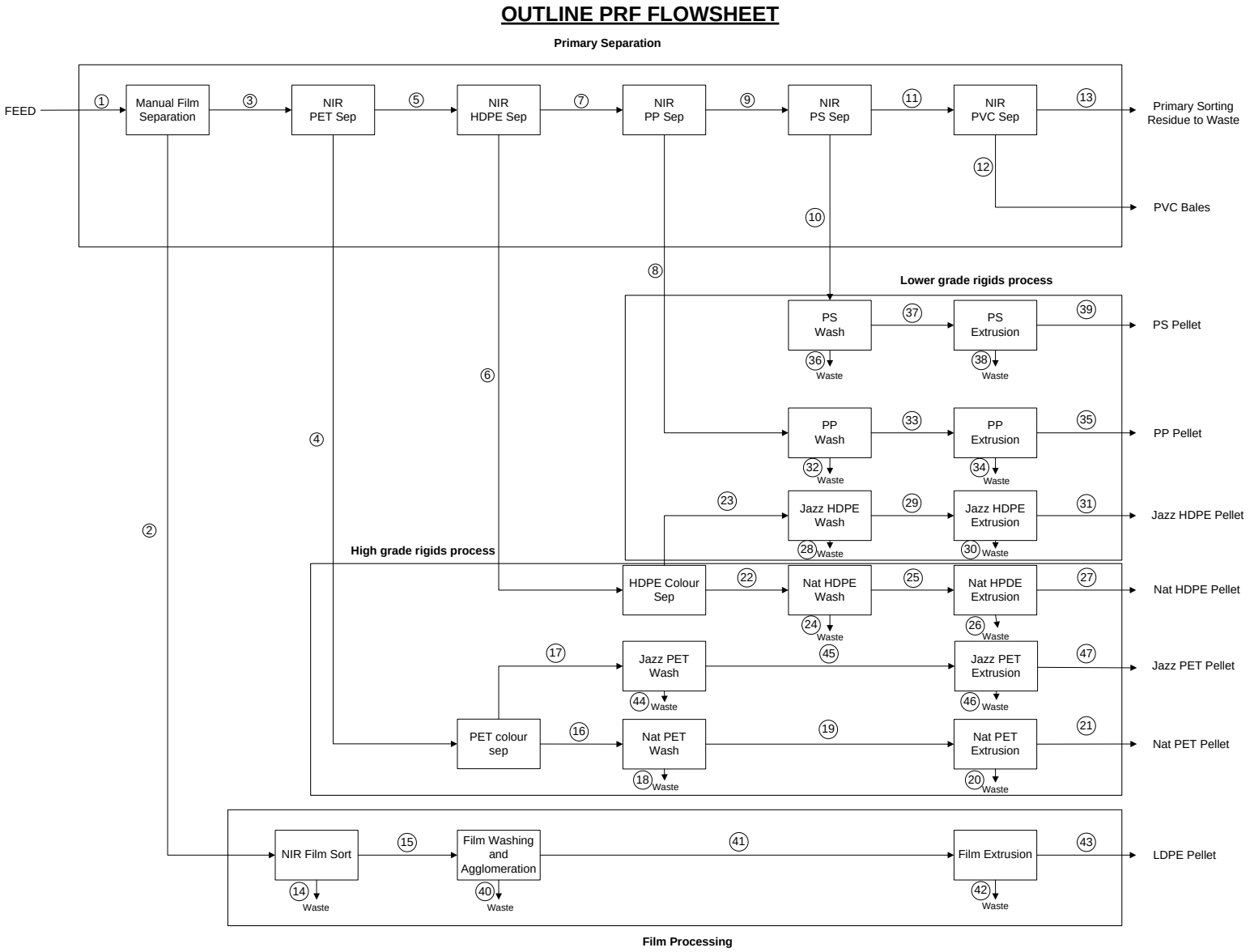
It is assumed that the full project cost is funded by a mix of 40% equity investment by the project shareholders and 60% bank lease finance.

The bank interest rates used in the model can be varied but in the base case. A base interbank lending interest rate of 2% is used, with a premium of 3% over base charged by the bank (total interest rate of 5%).

Plant and equipment is depreciated over a period of 10 years.

Loans are repaid over 5 years from completion of draw down of funds.

Figure 10 Process flowsheet for the integrated mixed plastic PRF and reprocessing facility



3.2.2 Separation efficiencies used in the integrated PRF and reprocessing facility mass balance model

The mass balance model used in the financial projections for the integrated PRF and reprocessing facility estimates the composition of the streams leaving each separation unit in the flowsheet by applying a separation efficiency to each of the components of the feed stream which enters that separator. This allows the model to recalculate all of the mass flows through the facility accurately when the feed composition is changed or the feed volume is altered.

The separation efficiency, termed Q in this context, is defined as the probability that a particle of that particular component of the feed stream will end up in the target output stream from the separator. For example, in Table 7 below the separation efficiencies for the NIR PET separator show that there is a 91% chance that a natural PET particle will end up in the target product stream (implying that 9% of the natural PET particles will end up incorrectly sorted in the reject stream) while there is a 41% chance that a film particle will also end up in the natural PET product stream. However if the quantity of film in the feed to the NIR sorter is small then there will only be a small quantity of film in the product stream.

The separation efficiencies in the table below are calculated from the compositional analysis data collected by Nextek during the practical trials.

Table 7 Separation efficiency assumptions used in the mass balance model

Separation Efficiencies

	Manual Film Separation	NIR PET Separation	NIR HDPE Separation	NIR PP Separation	NIR PS Separation	NIR PVC Separation	NIR Film Sorting	Film Washing and Agglomeration	Film Extrusion	PP Wash	PP Extrusion	PS Wash	PS Extrusion	HDPE Colour Separation	Jazz HDPE Wash	Jazz HDPE Extrusion	Natural HDPE Wash	Natural HDPE Extrusion	PET Colour Separation	Natural PET Washing	Natural PET Extrusion	Jazz PET washing	Jazz PET Extrusion
Stream in	1	3	5	7	9	11	2	15	41	8	33	10	37	6	23	29	22	25	4	16	19	17	45
Target stream out	2	4	6	8	10	12	15	41	43	33	35	37	39	23	29	31	25	27	17	19	21	45	47
Reject stream out	3	5	7	9	11	13	14	40	42	32	34	36	38	22	28	30	24	26	16	18	20	44	46
LDPE Film	98.9%	41%	30%	0%	0%	6%	85%	74%	93%	0%	0%	0%	97%	27%	67%	95.7%	87%	99.5%	35%	10%	97%	10%	97%
Natural PET	0%	91%	33%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	27%	0%	0.0%	20%	0.0%	3%	77%	97%	77%	97%
Colour PET	0%	72%	8%	15%	0%	0%	0%	0%	0%	0%	0%	0%	0%	27%	0%	0.0%	20%	0.0%	97%	77%	97%	77%	97%
Natural HDPE	0%	3%	98%	0%	0%	0%	0%	0%	0%	0%	0%	0%	97%	3%	67%	95.7%	87%	99.5%	35%	10%	97%	10%	97%
Colour HDPE	0%	3%	86%	5%	0%	0%	0%	0%	0%	0%	0%	0%	97%	97%	67%	95.7%	20%	99.5%	35%	10%	97%	10%	97%
PP	0%	0%	0%	91%	0%	0%	0%	0%	0%	58%	96%	0%	97%	27%	0%	95.7%	87%	99.5%	35%	10%	97%	10%	97%
PS	0%	0%	0%	0%	79%	4%	0%	0%	0%	0%	0%	59%	97%	27%	0%	95.7%	20%	99.5%	35%	10%	97%	10%	97%
PVC	0%	0%	0%	0%	0%	73%	0%	0%	0%	0%	0%	0%	0%	27%	0%	0.0%	20%	0.0%	35%	10%	0%	10%	0%
Metals	0%	46%	36%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	27%	0%	0.0%	20%	0.0%	35%	10%	0%	10%	0%
Closures	0%	2%	1%	0%	0%	4%	0%	0%	0%	0%	0%	0%	0%	27%	0%	0.0%	20%	0.0%	35%	10%	0%	10%	0%
Aseptic	0%	8%	4%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	27%	0%	0.0%	20%	0.0%	35%	10%	0%	10%	0%
Non-Packaging Plastic	0%	0%	0%	0%	0%	5%	0%	0%	0%	0%	0%	0%	0%	27%	0%	0.0%	20%	0.0%	35%	10%	0%	10%	0%
Paper/Card	0%	32%	21%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	27%	0%	0.0%	20%	0.0%	35%	10%	0%	10%	0%
Unknown	0%	68%	91%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	27%	0%	0.0%	20%	0.0%	35%	10%	0%	10%	0%
Fines	0%	35%	23%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	27%	0%	0.0%	20%	0.0%	35%	10%	0%	10%	0%

3.2.3 Mass balance model

Table 8 Mass balance for the integrated PRF and plastics reprocessing facility

The table below shows the composition and total annual quantity calculated by the model for each of the streams shown in the flowsheet for the integrated PRF and plastics reprocessing facility in Figure 10.

Mass Balance

Stream	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)
LDPE Film	24274	24007	267	109	158	47	111	0	111	0	111	7	104	3495	20511	71	38	64	7	0	7	34
Nat PET	13700	0	13700	12532	1168	388	780	0	780	0	780	0	780	0	0	12156	376	2796	9360	281	9080	282
Col PET	9227	0	9227	6644	2584	205	2378	367	2011	0	2011	5	2006	0	0	205	6438	47	158	5	153	149
Nat HDPE	6327	0	6327	186	6141	6009	132	0	132	0	132	0	132	0	0	121	64	109	12	0	12	5829
Col HDPE	2709	0	2709	70	2639	2265	374	18	356	0	356	0	356	0	0	46	24	41	5	0	4	68
PP	16570	0	16570	1	16569	0	16569	15013	1556	0	1556	5	1551	0	0	0	0	0	0	0	0	0
PS	553	0	553	1	552	0	552	0	552	433	118	5	113	0	0	0	0	0	0	0	0	0
PVC	1257	0	1257	1	1256	0	1256	0	1256	0	1256	918	338	0	0	0	0	0	0	0	0	0
Metals	238	0	238	109	130	47	83	0	83	0	83	1	82	0	0	71	38	64	7	7	0	34
Closures	38	0	38	1	37	0	37	0	37	0	37	2	35	0	0	0	0	0	0	0	0	0
Aseptic	9	0	9	1	8	0	8	0	8	0	8	8	0	0	0	0	0	0	0	0	0	0
Non-Packaging Plastic	440	0	440	1	440	0	439	0	439	0	439	21	419	0	0	0	0	0	0	0	0	0
Paper/Card	2902	0	2902	935	1967	404	1564	0	1564	0	1564	0	1564	0	0	611	324	550	61	61	0	293
Unknown	641	0	641	435	206	188	18	0	18	0	18	18	0	0	0	284	151	256	28	28	0	136
Fines	1113	0	1113	391	721	169	553	0	553	0	553	0	553	0	0	256	136	230	26	26	0	123
TOTAL	**79998**	**24007**	**55991**	**21415**	**34576**	**9723**	**24853**	**15399**	**9454**	**433**	**9021**	**987**	**8033**	**3495**	**20511**	**13825**	**7590**	**4160**	**9665**	**409**	**9256**	**6949**

IN	79998
OUT	79998
difference	0

Mass Balance

Stream	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)	Mass(te)
LDPE Film	13	4	30	0	29	4	9	0	8	0	0	0	0	0	0	0	0	5333	15178	1134	14044	34	4
Nat PET	106	225	56	56	0	106	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	86	289
Col PET	56	119	30	30	0	56	0	0	0	367	0	0	0	0	0	0	0	0	0	0	0	1481	4957
Nat HDPE	180	758	5071	25	5046	59	121	5	116	0	0	0	0	0	0	0	0	0	0	0	0	58	6
Col HDPE	2197	54	14	0	14	725	1472	63	1409	18	0	0	0	0	0	0	0	0	0	0	0	22	2
PP	0	0	0	0	0	0	0	0	0	6306	8708	371	8337	0	0	0	0	0	0	0	0	0	0
PS	0	0	0	0	0	0	0	0	0	0	0	0	0	178	256	8	248	0	0	0	0	0	0
PVC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Metals	13	27	7	7	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34	4
Closures	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aseptic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Non-Packaging Plastic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paper/Card	110	234	59	59	0	110	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	292	32
Unknown	51	109	27	27	0	51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	136	15
Fines	46	98	25	25	0	46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	122	14
TOTAL	**2774**	**1631**	**5318**	**229**	**5089**	**1172**	**1601**	**69**	**1532**	**6691**	**8708**	**371**	**8337**	**178**	**256**	**8**	**248**	**5333**	**15178**	**1134**	**14044**	**2265**	**5324**

3.2.4 Operating costs

The operating cost assumptions for the integrated mixed plastics PRF and reprocessing model are mostly derived from data supplied by Nextek but some is based on Axion's own experience of running a plastic recycling plant.

Table 9 Operating assumptions for the mixed plastics reprocessing model

Plant input	**80,000** te/yr										
	Total te/yr	No. of Shifts	OEE		Actual te/hr	Installed capacity te/hr	Plant operating hrs/yr	Effective plant op hrs/yr			
MRF bale breaking and NIR sorting	55,724	4		60%	6.7	11	8320	4992			
Flake washing	46,971	4		70%	5.6	8.1	8320	5824			
PET extrusion	14,989	4		70%	1.8	2.6	8320	5824			
HDPE extrusion	5,318	4		70%	0.6	0.9	8320	5824			
PP, PS and Jazz PE production	10,565	4		70%	1.3	1.8	8320	5824			
Film bale breaking and sorting	24,007	4		60%	2.9	4.8	8320	4992			
Film agglomeration and washing	20,511	4		70%	2.5	3.5	8320	5824			
Film extrusion	15,178	4		70%	1.8	2.6	8320	5824			
Waste processing	24,880	1		60%	12.0	20	2080	1248			
Total saleable plant output	**44,596 te/yr**	**=**		**56% Overall yield**							
Total new equipment cost £'000	**29,495**										
			Fuel for mobile plant		133,678	25	litres/hr		109	p/litre	
			Transport		0	0	£/te product output				
			Packaging		222,980	5	£/te product output				
			Water		296,919	2.2	te water/te washed material		2	£/te	
			PET wash process gas		124,426	300	KWh/te		3	p/kWhr	
			HDPE wash process gas		62,544	300	KWh/te		3	p/kWhr	
			Base load power		133,453	200	KW		8.02	p/kWhr	
			MRF baler power		3,907	8	KWh/te		1	£/te power	
			PET wash process power		601,120	350	KWh/te		28	£/te power	
			HDPE wash process power		272,929	350	KWh/te		28	£/te power	
			PP wash process power		479,176	388	KWh/te		31	£/te power	
			PS wash process power		13,489	388	KWh/te		31	£/te power	
			PE wash process power		86,313	388	KWh/te		31	£/te power	
			Film wash process power		481,330	250	KWh/te		20	£/te power	
			PET extrusion power		390,697	325	KWh/te		26	£/te power	
			HDPE extrusion power		132,652	325	KWh/te		26	£/te power	
			PP extrusion power		217,307	325	KWh/te		26	£/te power	
			PS extrusion power		6,462	325	KWh/te		26	£/te power	
			PE extrusion power		39,944	325	KWh/te		26	£/te power	
			Film extrusion power		366,050	325	KWh/te		26	£/te power	
						3,224,829	total power cost		72	£/te output power cost	
			Total running cost		**4,065,376**	=		91	£/te output		
Annual management & admin overheads			Business rates		200,000	£2	/sq ft	100,000	sq ft		
			Site rental		600,000	£6	/sq ft	100,000	sq ft		
		Production staff	MRF bale breaking and NIR sorting		480,000	6	operators/shift	20000	avg job cost		
			Flake washing		160,000	2	operators/shift	20000	avg job cost		
			PET extrusion		80,000	1	operators/shift	20000	avg job cost		
			HDPE extrusion		80,000	1	operators/shift	20000	avg job cost		
			PP, PS and Jazz PE production		240,000	3	operators/shift	20000	avg job cost		
			Film bale breaking and sorting		240,000	3	operators/shift	20000	avg job cost		
			Film agglomeration and washing		160,000	2	operators/shift	20000	avg job cost		
			Waste processing		40,000	2	operators/shift	20000	avg job cost		
			Yard team labour		40,000	2	staff	20000	avg job cost		
			maintenance staff		120,000	4	Staff	30000	avg job cost		
			QC/lab staff		60,000	3	Staff	20000	avg job cost		
			Overhead staff costs		200,000	4	Staff	50000	avg job cost		
						87	Total staff =	43	£/te output		
			maintenance spares/ contracts		1,522,730	5%	of new capex plus	4,000	£/month general maintenance cost		
			Loader + Fork lift rent		40,000						
			Service contracts		80,000						
			Audit costs		10,000						
			Insurance		120,000						
			Communications		20,000						
			Travel		60,000						
			Marketing & PR		80,000						
			Total		**4,632,730**	=		104	£/te output		
Total operating costs					**8,698,105**	=		195	£/te output		
Total net revenue (from mass balance)					24,251,761			544	£/te output		
Cost of input (from mass balance)					5,600,000			126	£/te output		
Total net revenue					**18,651,761**	=		418	£/te output		
Operating margin		**53%**			**9,953,656**	=		223	£/te output		

Notes on the operating assumptions:

- OEE stands for overall equipment effectiveness. OEE is a measure of how effectively the productive equipment in the plant is used in practice. It is defined as follows:

$$\text{OEE} = \text{capacity rate x quality rate x availability}$$

$$\text{capacity rate} = \frac{\text{actual throughput}}{\text{rated throughput}}$$

$$\text{quality rate} = \%\ \text{of on specification product}$$

$$\text{availability} = \frac{\text{actual run hours}}{\text{available run hours}}$$

- World class production performance is generally accepted to be defined by an OEE of 85%. An OEE of 70% is used in these projections because this is more typical of well-run complex recycling operations. The availability factor in the OEE calculation allows for downtime for maintenance
- Process yields are calculated for each process stream and for each material type using the detailed mass balance shown in tables 6 and 7. The mass balance model estimates the composition and flow rate for each stream within the process flowsheet from the feed material composition and the separation efficiency for each of the process units within the plant. These separation efficiencies are different for each process unit and in most cases they are different for each material type that is fed to the process unit. The individual separation efficiencies are calculated by Axion within the model from base data supplied by Nextek.
- It is assumed that all of the sections of the plant will run on a 24 hour basis, 7 days per week, requiring the plant to be manned with 4 shifts of operators. This way the maximum production is achieved from what is a very capital-intensive process.
- The model assumes that the clear PET and natural HDPE streams will each have dedicated washing and extrusion plants with the aim of producing high value food grade pellet. The Jazz PET and PE, PP and PS streams will be processed in a simpler multi-purpose flake washing and extrusion unit. Materials will be processed through this unit in batches in order to maximise usage of the production plant and allow flexibility to cope with variations in composition of the feed material. The full integrated facility therefore includes four separate full washing and extrusion lines (food grade PET, food grade HDPE, other rigids and films). The base case plant requires one extruder each for PET, HDPE and film and two extruders for other rigids in order to process the full throughput.
- Power, water and gas consumption rates and prices are derived from data collected by Nextek from the trial partners. The model relates these costs to the mass flows of the relevant materials so that when the plant throughput is altered all of the costs vary accordingly.
- The model assumes that the plant is built on an existing site within a building which is rented at a cost of £6/sq ft per year. A 100,000 sq ft building is assumed for the base case. Both the site rental cost and the building size can be altered in the model.
- Nextek provided capital cost estimates for all the elements of the integrated plant at the capacity required for the base case throughput. In order to adjust the capital cost as the plant throughput is changed the capital cost section of the model relates the capital cost of the plant to the capacity required for each process unit (from the mass balance) and to the cost of standard process units with costs and capacities provided to Axion by Nextek. A 0.6 power law is used to adjust the capital cost of each process unit upwards or downwards as the plant throughput varies. A 0.6 power law is generally accepted by process engineers to be a reasonable factor to adjust capital costs for throughput in an initial scoping capital cost estimate of this type.
- Manning levels for each section of the plant have been estimated for the base case by Axion in consultation with Nextek. The job cost per plant operator shown in the operating assumptions is estimated by Axion and

includes their salary, employer's national insurance and an allowance for training, personal protective equipment and other costs directly related to employment of an individual operator.

- Fixed costs for insurance, communications, marketing, etc are estimated by Axion.

3.2.5 Price assumptions and overall mass balance

Nextek estimated the following material prices and overall mass balance for the product fractions from the mixed plastics reprocessing plant:

Table 10 Base case mass balance assumptions for integrated PRF and reprocessing facility for film and mixed rigids including bottles

input	**80000 t/yr**	
film	**24000**	**30%**
rigids	**56000**	**70%**

Inputs	Total (t/yr)	%	cost/t	cost
Film	24000	30%	£0	£0
Mixed Rigids inc PET and HDPE	56000	70%	£100	£5,600,000
Total Input	80000	100%	£70.0	£5,600,000

Products	yield	tpa	price/te	PRN/PERN	revenue
Clear PET Pellet	12%	9256	£800	£20	£7,590,091
Jazz PET Pellet	6%	5102	£500	£20	£2,652,913
PVC Bales	1%	987	£25	£20	£44,437
HDPE Pellet	6%	5089	£800	£20	£4,173,200
PP pellet	10%	8337	£500	£20	£4,335,308
PS pellet	0%	248	£500	£20	£128,910
LDPE Film-derived pellet	18%	14044	£450	£20	£6,600,552
Jazz PE Pellet	2%	1532	£500	£20	£796,887
Waste for combustion	14%	11529	-£45		-£518,783
waste for landfill	30%	23873	-£65		-£1,551,753
TOTAL	100%	79998			£24,251,761

Ave selling price for products = £590 /te

Notes:

- The base case model assumes that the facility is designed to process a total of 80,000t/yr of feed material containing the full range of plastics that would be collected by a household recyclable MRF. This includes 30% plastic films and the full amount of clear PET and natural HDPE that is discarded by the householders. Clear PET and natural HDPE bottles are the most valuable components of the plastic waste stream. The MRF section of this report models a scenario where these materials are extracted at the MRF. The sensitivity analysis in section 3.5 below models the affect on the plastics reprocessing facility of various materials being extracted from the feed at the MRF.
- It is assumed that the facility will be able to earn packaging recovery notes (PRNs) or packaging export recovery notes (PERNs) for the materials that are produced. The value of PRNs and PERNs tends to fluctuate throughout the year. A conservative figure of £20/t has been assumed but this can be varied in the model.
- The model assumes that the dry residue material from the primary NIR sorting section of the plant will be suitable for combustion in waste to energy plants or cement kilns at a somewhat lower gate fee than landfill. The remainder of the waste materials from the wash plants, extrusion, etc is assumed to attract full landfill cost.
- The feed costs and product selling prices used in the base case were provided to Axion by Nextek following consultation with the trial partners. The sensitivity analysis in section 3.5 models the impact of both lower selling prices and higher feed costs on the viability of the facility.

3.2.6 Capital costs

The base case capital cost for the full mixed plastics reprocessing plant is estimated to be £29.5 million, assuming that the facility is constructed inside an existing rented building. Costs are estimated below:

Table 11 Capital cost estimate for base case integrated PRF and reprocessing facility for film and mixed rigids including bottles

Film bale breaking and sorting	1,462
Film bale breaking and sorting conveyors and installation	365
Film agglomeration	1,854
Film agglomeration conveyors and installation	463
Film extrusion	1,156
Film extrusion conveyors and installation	289
Rigids bale breaking and NIR/colour sorting section	4,496
Rigids bale breaking and sorting conveyors and installation	1,124
Rigids hot flake washing	7,555
Rigids hot flake washing conveyors and installation	1,889
PET extrusion	2,114
PET extrusion conveyors and installation	529
HDPE extrusion	2,114
HDPE extrusion conveyors and installation	529
PP/PS/PE cleaning and extrusion	1,117
PP/PS/PE cleaning and extrusion conveyors and installation (2 extruders)	305
Civils	1,200
Design and project management	800
Total project cost £'000	**29,495**

Notes:

- Build time is estimated at 12 months and throughput is expected to grow to full output over a period of 12 months after initial start-up.
- The capital cost estimates used in the model were supplied by Nextek.
- The model includes a capital cost adjustment factor which uses a 0.6 power law to adjust the capital cost up or down if the capacity required for the rated throughput of the particular section of the plant does not match the capacity for which the capital cost was estimated.
- The model includes an installation cost factor which adjusts the base equipment costs. In the base case this factor adjusts the equipment costs provided by Nextek upwards by 25%.
- The project cost estimate includes £1.2 million of civil works and building costs and £800,000 of project management and design costs. These sums were estimated by Axion and assume that the plant is built inside an existing building.
- The capital costs refer to a brand new installation. It might be possible to reduce capital costs with second hand equipment.

Table 12 Summary projections

£'000	2010	2011	2012	2013	2014	2015
Tonnage processed	0	30,000	80,000	80,000	80,000	80,000
Profit and Loss						
Sales Revenue	0	9,094	24,252	24,252	24,252	24,252
Direct operating costs	-0	-3,625	-9,665	-9,665	-9,665	-9,665
Gross Profit	**0**	**5,470**	**14,586**	**14,586**	**14,586**	**14,586**
Gross Margin	**0%**	**60%**	**60%**	**60%**	**60%**	**60%**
Indirect costs	-4,633	-4,633	-4,633	-4,633	-4,633	-4,633
EBITDA	**-4,633**	**837**	**9,954**	**9,954**	**9,954**	**9,954**
Depreciation	-1,041	-3,093	-3,093	-3,093	-3,093	-3,093
EBIT	-5,674	-2,256	6,860	6,860	6,860	6,860
Interest	-259	-656	-553	-443	-319	-49
Pre-tax profit	-5,933	-2,912	6,307	6,417	6,541	6,811
Taxation (estimate)	0	0	-1,892	-1,925	-1,962	-2,043
Dividends distributed	0	0	0	-2,246	0	-2,384
Net profit to reserves	**-5,933**	**-2,912**	**4,415**	**2,246**	**4,579**	**2,384**
Cash Flow						
Opening bank balance	0	-1,024	-269	3,125	4,438	5,986
Revenue (inc VAT)	0	10,686	28,496	28,496	28,496	28,496
Construction costs (inc VAT)	-34,656	0	0	0	0	0
Operating costs (inc VAT)	-5,443	-9,702	-16,800	-16,800	-16,800	-16,800
VAT (paid)/recovered	5,389	713	-1,582	-1,742	-435	-1,742
Cash flow before debt service	**-34,711**	**672**	**9,845**	**13,078**	**15,698**	**15,939**
Lease debt service	-2,664	-4,769	-4,940	-5,066	-4,141	-67
Cash flow after leases	**-37,375**	**-4,097**	**4,905**	**8,012**	**11,557**	**15,872**
Shareholder loan debt service	-144	-1,172	-1,780	-1,682	-1,400	-1,400
Corporation tax (approx)	0	0	0	-1,892	-1,925	-1,962
Dividends paid	0	0	0	0	-2,246	0
Operating surplus/(deficit)	**-37,519**	**-4,244**	**3,393**	**1,313**	**1,548**	**6,524**
Financing inflow	36,495	5,000	0	0	0	0
Closing bank balance	**-1,024**	**-269**	**3,125**	**4,438**	**5,986**	**12,510**
Balance sheet						
Fixed assets	28,453	25,360	22,267	19,173	16,080	12,986
Current assets	-1,024	-269	3,125	4,438	5,986	12,510
Liabilities	19,513	20,088	15,973	11,947	5,822	6,869
Net assets	7,916	5,003	9,418	11,664	16,243	18,627
Equity	13,848	13,848	13,848	13,848	13,848	13,848
Reserves	-5,933	-8,845	-4,430	-2,184	2,395	4,779
	7,916	5,003	9,418	11,664	16,243	18,627

3.4 Cash flow projection for incremental investment

The model also includes a cash flow forecast for the addition of a PRF and integrated reprocessing facility to an existing recycling operation.

Table 13 Incremental cash flow projection for the base case integrated PRF and reprocessing facility

Year		**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Mass balance parameters (tonnes)											
Capacity utilisation		0%	38%	100%	100%	100%	100%	100%	100%	100%	100%
Total input material (from mass balance)		**0**	**30,000**	**80,000**	**80,000**	**80,000**	**80,000**	**80,000**	**80,000**	**80,000**	**80,000**
mixed plastic landfill diversion			56%	56%	56%	56%	56%	56%	56%	56%	56%
useful output from input material (from mass balance)		**0**	**16,723**	**44,596**	**44,596**	**44,596**	**44,596**	**44,596**	**44,596**	**44,596**	**44,596**
Unit Income											
Input material cost from mass balance		£70.0	£70.0	£70.0	£70.0	£70.0	£70.0	£70.0	£70.0	£70.0	£70.0
Average product sales price from mass balance		£590	£590	£590	£590	£590	£590	£590	£590	£590	£590
Incremental income from additional mixed plastic throughput											
Input material cost		0	-2,100,000	-5,600,000	-5,600,000	-5,600,000	-5,600,000	-5,600,000	-5,600,000	-5,600,000	-5,600,000
Product Sales		0	9,870,861	26,322,297	26,322,297	26,322,297	26,322,297	26,322,297	26,322,297	26,322,297	26,322,297
Total income		**0**	**7,770,861**	**20,722,297**	**20,722,297**	**20,722,297**	**20,722,297**	**20,722,297**	**20,722,297**	**20,722,297**	**20,722,297**
Incremental operating costs for new equipment											
variable costs from op assumptions		0	1,524,516	4,065,376	4,065,376	4,065,376	4,065,376	4,065,376	4,065,376	4,065,376	4,065,376
fixed costs from op assumptions		0	4,632,730	4,632,730	4,632,730	4,632,730	4,632,730	4,632,730	4,632,730	4,632,730	4,632,730
Landfill cost for waste fraction		0	776,451	2,070,536	2,070,536	2,070,536	2,070,536	2,070,536	2,070,536	2,070,536	2,070,536
New lease (£20/month/'000 over 5 years)		6,790,702	6,790,702	6,790,702	6,790,702	6,790,702	1,358,140	1,358,140	1,358,140	1,358,140	1,358,140
Total costs		**6,790,702**	**13,724,399**	**17,559,343**	**17,559,343**	**17,559,343**	**12,126,782**	**12,126,782**	**12,126,782**	**12,126,782**	**12,126,782**
Operating Cash Flow		**-6,790,702**	**-5,953,537**	**3,162,953**	**3,162,953**	**3,162,953**	**8,595,515**	**8,595,515**	**8,595,515**	**8,595,515**	**8,595,515**
Capital Expenditure (from capex schedule)											
Equipment, buildings and working cap funded by equity	1,200,000	0	0	0	0	0	0	0	0	0	0
Plant (funded by Lease) from Capex schedule	28,294,592										
Net Cash Flow	-1,200,000	-6,790,702	-5,953,537	3,162,953	3,162,953	3,162,953	8,595,515	8,595,515	8,595,515	8,595,515	8,595,515
Cumulative Cash Flow	-1,200,000	-7,990,702	-13,944,239	-10,781,286	-7,618,333	-4,455,379	4,140,136	12,735,651	21,331,166	29,926,682	38,522,197
10 yr IRR (Internal Rate of Return)	27%										
NPV (Net Present Value)	14,438,969	10% Discount rate									

The base case version of the incremental cash flow projection (shown above) includes all of the elements of the PRF and integrated reprocessing facility. In practice an existing recycler is likely to already have some of these elements in place. The incremental cash flow model will therefore be most useful when considering sensitivity scenarios where the facility to be constructed only includes some of the elements of a full plant. The sensitivity analysis in section 3.5 considers several such scenarios.

Notes on the incremental cash flow projection:

- The forecast picks up throughput, mass balance, price, capital cost and operating cost assumptions from the main model.
- The projection assumes that the equipment is funded entirely by a 5 year lease with a 20% residual value as described in the MRF model.
- Building costs are assumed to be self-funded by the plant operator. This funding is taken into account in the 10 year project Internal Rate of Return (IRR) and Net Present Value (NPV) calculations.
- The projection also includes an option where the equipment is part-funded by a grant, which improves the project IRR.

3.5 Sensitivity analysis

3.5.1 Choice of scenarios

A number of sensitivity scenarios were identified through discussion with WRAP and Nextek as follows:

- Reduced finished product price;
- Cost or gate fee for baled mixed plastics PRF and reprocessing plant feed material;
- Throughput above or below the base case of 80,000t/yr;
- Reduced and increased process yield;
- Higher utility costs;
- Higher or lower labour costs;
- Higher or lower capital cost; and
- Higher waste fraction removed in the primary separation stage.

These have been applied to the model in order to undertake a sensitivity analysis.

Axion has conducted further sensitivity analysis to model the impact of varying the feed mix for the plant in various scenarios including:

- Excluding films from the feed;
- Excluding clear PET bottles and natural HDPE bottles from the feed; and
- Processing only films;
- Near infra red sorting the feed to produce baled material of single polymer type without flake washing or extrusion.

These scenarios may be considered either as stand-alone ventures or as additions to an existing recycling facility which already includes some of the elements of the full base case integrated PRF and reprocessing facility.

3.5.2 Other sensitivities considered but not modelled in detail

Combustion of the waste fractions for heat and/or power

The base case model assumes that the waste fractions from the washing processes in the reprocessing facility are not suitable for use as fuel because of their high water content and they must therefore be landfilled. The same also applies to the waste fraction from the extrusion process as this is likely to include a high proportion of metal filter screens.

However the base case model does assume that the residue fraction from the PRF section of the plant (NIR sorting) can be burned as a fuel in cement plants. There are several plants in the UK which can accept this type of waste or expect to be able to accept it shortly provided the chlorine content of the material is very low. The base case model includes a PVC sorting unit so it is assumed that the residue fraction will have low enough chlorine content to be viable as a cement fuel. This would need to be proven in practice. The base case model assumes that the ex-works disposal cost for the residue fraction from the PRF when supplied as cement plant fuel is £20/t less than the cost of landfill.

There is a possibility that the PRF residue fraction and potentially the wet waste fractions from the wash processes could be used by others as fuel for combustion but at present in the UK most of these facilities charge a gate fee that is close to landfill cost for these materials.

The possibility of using these wastes for power generation in a combined heat and power plant was also considered. Initial investigations indicate that the high capital cost of a power plant that complies with the EU Waste Incineration Directive means that such a plant would not be economically viable when burning a feed material like the mixed waste from the PRF with a relatively high calorific value (20-23MJ/Kg). This is because such plants derive a large proportion of their revenue from the gate fees that they charge for the feed material. When the calorific value of the feed is high this means that the gate fee revenue per unit power production is low. Capital cost is largely related to power output so the facility would be unable to generate sufficient revenue to repay its investors.

Regional factors

The study was asked to consider regional factors. Mixed waste plastic bales can be transported significant distances around England, Scotland and Wales with relatively low variations in cost between destinations. Transport of waste plastic to Northern Ireland from the rest of the UK is more expensive and time consuming.

However the sensitivity analysis below shows that there are significant economies of scale for an integrated PRF and reprocessing facility. It therefore makes sense to locate large integrated recycling facilities of the type modelled in this project close to centres of population and centres of the motorway network.

End markets for the recovered polymers tend to be found right across Europe so locations with good distribution access to Europe are also favoured.

An integrated PRF and reprocessing facility is a relatively compact operation which does not require extensive external yard space and causes limited environmental impact so cost of land is not a major consideration for locating such a facility.

Scotland

Central Scotland has good motorway access and significant centres of population. Waste plastic can be transported relatively easily to or from this area. It may be a suitable location for an integrated PRF and reprocessing facility.

Northern Ireland

The relatively low population and high cost of transport to Northern Ireland make this a more difficult location for a large integrated PRF and reprocessing facility. However the cost of transport for baled mixed plastics to England, Scotland or Wales from Northern Ireland is relatively low due to the availability of back-loads. The best option for this region may be to collect mixed plastic in MRFs and move it to large integrated facilities elsewhere in the UK.

Wales

South Wales already hosts a concentration of plastics reprocessing facilities. It has good motorway access to the Midlands, South and South West of England. It may therefore be a good location for an integrated PRF and reprocessing facility.

3.5.3 Sensitivity analysis results

Table 14 Scenarios adjusting prices for the base case integrated PRF and reprocessing facility

Scenario	Base case value	Sensitivity value	10 yr Project IRR	7 yr Equity IRR	Yr5 EBITDA £m	Comment
Base case	-	-	+19%	+37%	9.9	Investor returns are attractive for the base case
Reduced prices for recycled polymer	PET/HDPE £800/t PP/PS/PE £500/t LDPE £450/t	PET/HDPE £650/t PP/PS/PE/coloured PET £400/t LDPE £350/t	+2%	+3%	4.9	Project returns are very sensitive to changes in selling price. Note however that this sensitivity assumes that prices are reduced to these levels for the full 10 year duration of the projection. This may be pessimistic
Greatly reduced prices for recycled polymer fractions	PET/HDPE £800/t PP/PS/PE £500/t LDPE £450/t	PET/HDPE £500/t PP/PS/PE/coloured PET £300/t LDPE £250/t	Very negative	Very negative	0.8	This scenario assumes that the facility is unable to achieve food grade standard for the clear PET and natural HDPE fractions and also suffers severe price pressure on the other products
Reduced price for the feed material	£70/t average cost for film and mixed plastic feed bales	£49/t average cost for film and mixed plastic feed bales	+23%	+43%	11.6	Significant improvement in returns if the feed price can be reduced.
Increased price for feed material	£70/t average cost for film and mixed plastic feed	£100/t average cost for film and mixed plastic feed bales	+12%	+26%	7.6	Project returns are sensitive to feed cost increases
Pays greatly increased price for feed material due to high natural HDPE and clear PET content	£70/t average cost for film and mixed plastic feed	£150/t average cost for film and mixed plastic feed bales	-4%	Very negative	3.6	Feed cost over about £150/t for full mixed plastics including films, natural HDPE and clear PET is not attractive
Mixed plastics reprocessing plant charges a gate fee instead of paying for feed material when pellet selling prices are low	£70/t cost for mixed plastic feed bales Selling prices: PET/HDPE £800/t PP/PS/PE £500/t LDPE £450/t	£30/t gate fee charged for mixed plastic feed bales Selling prices PET/HDPE £500/t PP/PS/PE £400/t LDPE £350/t	+21%	+40%	10.7	Gate fee necessary for survival at low polymer prices.
Increased prices for recycled polymers	PET/HDPE £800/t PP/PS/PE £500/t LDPE £450/t	PET/HDPE £900/t All others at £600/t	+32%	+54%	15.0	Returns become very attractive if polymer prices rise as a result of customers placing more value on recycled content

Table 15 Scenarios adjusting throughput for the base case integrated PRF and reprocessing facility

Scenario	Base case value	Sensitivity value	10 yr Project IRR	7 yr Equity IRR	Yr5 EBITDA £m	Comment
Base case	-	-	+19%	+37%	9.9	Investor returns attractive for the base case
Higher plant throughput	80,000t/yr Capex £29.5m	100,000t/yr Capex £33.4m	+24%	+45%	13.5	Higher throughput improves investor returns due to high fixed costs which can be spread over more production
Higher plant throughput and very low pellet prices	80,000t/yr PET/HDPE £800/t PP/PS/PE £500/t LDPE £450/t	100,000t/yr PET/HDPE £500/t PP/PS/PE £400/t LDPE £250/t	-10%	very negative	2.7	Plant could not survive with very low pellet prices, even if throughput is significantly higher
Lower plant throughput	80,000t/yr Capex £29.5m	50,000t/yr Capex £22.7m	+6%	+14%	4.7	Throughput less than 50,000t/yr does not look financially attractive.

Table 16 Scenarios adjusting process yield, operating costs and capital cost for the base case integrated PRF and reprocessing facility

Scenario	Base case value	Sensitivity value	10 yr Project IRR	7 yr equity IRR	Yr5 EBITDA £m	Comment
Base case	-	-	+19%	+37%	9.9	
Lower process yield (modelled by reducing all wash process yields by 10%)	56%	52%	+13%	+29%	8.0	Project viability is sensitive to process yield. Yield reductions cut investor returns significantly.
High process yield (modelled by increasing all wash process yields by 10%	56%	59%	+24%	+44%	11.9	Improvements in washing efficiency would make a big improvement in project returns
High process yield (modelled by increasing all NIR sorting separation efficiencies to 97%)	56%	60%	+24%	+44%	12.1	Increasing NIR sorting efficiency may be easier to achieve and has a similar effect. NIR sorters should be able to achieve higher yields in continuous operation
Higher power costs	8.02p/KWh	10.7p/KWh	+16%	+33%	8.9	Power costs are important because they are the largest component of direct costs
Higher water cost	£2/t	£2.5/t	+19%	+37%	9.9	Insensitive to water cost
Lower labour costs (30% less people)	87 staff	61 staff	+21%	+40%	10.5	Relatively insensitive to staff numbers
Higher labour costs (28% more people)	87 staff	111 staff	+17%	+35%	9.4	Relatively insensitive to staff numbers
Higher capital costs (+20%)	£29.5million	£37 million	+12%	+29%	9.6	Higher capital cost makes a big difference to investor returns but has little impact on operating profit
Lower capital costs	£29.5million	£23million	+26%	+45%	10.3	Lower capital cost is a big advantage for investors. An 8% reduction in capital cost improves project IRR from 19% to 26%. This suggests a grant to pay for equipment would make a significant difference to the project economics The current capital cost estimate assumes that all of the equipment that is installed is brand new. There are sections of the facility which could potentially be equipped with less expensive second hand equipment in order to cut capital cost.
Higher percentage residue fraction from the primary sort	10%	25%	+16%	+33%	9.2	Higher contamination in the feed is not a big issue if it can be removed at an early stage by the NIR sorting system because this is relatively cheap to operate

Table 17 Scenarios modelling exclusion of film processing for the base case integrated PRF and reprocessing facility

Scenario	Base case value	Sensitivity value	10 yr Project IRR	7 yr equity IRR	Yr5 EBITDA £m	Comment
Base case	-	-	+19%	+37%	9.9	
No film in feed with mixed baled rigids feed cost (including PET and HDPE bottles) of £100/t	56,000t rigids + 24,000t film (30% film) with average feed cost of £70/t	56,000t rigids and no film but feed cost of £100/t (£24m capex)	7%	17%	5.3	Removing film from feed will increase the average value of the feed material. It appears that film processing makes greater returns than processing mixed rigids and bottles in the base case scenario
No film in feed with mixed baled rigids feed cost (including PET and HDPE bottles) of £50/t	56,000t rigids + 24,000t film (30% film) with average feed cost of £70/t	56,000t rigids and no film but feed cost of £50/t (£24m capex)	+18%	+34%	8.1	Mixed baled rigid cost needs to be maximum of about £50/te when films are excluded when the plant is built at a scale of 56,000t/yr
No film in feed with mixed baled rigids feed cost (including PET and HDPE bottles) and base case average feed cost of £70/t The aim of this scenario is to assess whether processing 24,000t/yr of film with rigids adds value to the business	56,000t rigids + 24,000t film (30% film) with average feed cost of £70/t	56,000t rigids and no film and base case feed cost of £70/t (£24m capex)	+14%	+29%	6.9	Film processing appears to add value to the integrated PRF as there is no significant reduction in project returns if film processing is removed from the base case model, despite less turnover to absorb fixed costs.
No film in feed with mixed baled rigids feed cost (including PET and HDPE bottles) of £100/t Higher rigids throughput of 80,000t/yr	56,000t rigids + 24,000t film (30% film) with average feed cost of £70/t	80,000t rigids and no film but feed cost of £100/t (£29m capex)	+17%	+34%	9.2	Rigids-only facility looks more attractive at a throughput of 80,000t/yr

The scenarios considered in this section indicate that an integrated PRF and reprocessing facility that handles only mixed rigid plastics, excluding films should be commercially viable at the base case rigids throughput of 56,000t/yr provided the mixed baled rigid feed material that it receives from the MRFs costs no more than about £50/t and the pellet products can be sold at the prices used for the base case scenario. The current price for mixed baled other rigids and bottles including PET and HDPE in the UK is between £50-£100/t. The integrated PRF and reprocessing facility should be able to make attractive returns with a mixed rigids feed cost (including PET and HDPE bottles) of £100/t if the plant is built with a capacity over 80,000t/yr

Table 18 Scenarios modelling addition of capacity for other rigids to a reprocessing facility that already handles clear PET and natural HDPE

Scenario	Base case value	Sensitivity value	10 yr Project IRR	7 yr equity IRR	Yr5 EBITDA £m	10 yr IRR for addition of this capacity to an existing facility	Comment
Base case	-	-	+19%	+37%	9.9	27% (as shown in Table 13)	
Standalone plastics processing plant for mixed rigids excluding PET and HDPE. No film and no natural HDPE or clear PET in feed with feed cost of £70/t This scenario models the situation where an existing recycler is already separating and reprocessing HDPE and PET bottles and wishes to consider adding processing capacity for other rigids but not films so that they can increase their material recovery rate from mixed rigids collected by MRFs	56,000t rigids + 24,000t film (30% film) with average feed cost of £70/t	56,000t rigids and no clear PET, Natural HDPE or film with base case feed cost of £40/t for rigids only (capex £19m)	+8%	+18%%	4.4	+9%	Just viable at 56,000t/yr scale with £40/t feed cost and base case selling prices.
As previous scenario but with feed volume of 80,000t/yr No film and no natural HDPE or clear PET in feed with feed cost of £40/t	56,000t rigids + 24,000t film (30% film) with average feed cost of £70/t	80,000t rigids and no clear PET, Natural HDPE or film with feed cost of £40/t and base case pellet sales prices (Capex £23m)	+18%	+34%	7.6	+26%	Attractive at 80,000t/yr scale as either a stand alone investment or an addition to an existing facility with £40/t feed cost and base case selling prices
As previous scenario including higher throughput of 80,000t/yr but lower average sales price of £400/t for PP, PE, and PS pellet rather than £500/t in base case	56,000t rigids + 24,000t film (30% film) with feed cost of £70/t	80,000t rigids and no clear PET, Natural HDPE or film with reduced feed cost of £20/t and £400/t sales price for all pellet (Capex £23m)	+9%	+20%	5.4	+10%	Just viable at 80,000t/yr scale provided feed cost can be cut to £20/t when selling price drops to £400/t for pellet.

Table 19 Scenarios modelling addition of processing capacity for film to an existing facility

Scenario	Base case value	Sensitivity value	10 yr Project IRR	7 yr equity IRR	Yr5 EBITDA £m	10 yr IRR for addition of this capacity to an existing facility	Comment
Base case	-	-	+19%	+37%	9.9	-	
Film processing only with feed cost of £nil/t for 24,000t/yr Base case overall yield of 63% LDPE pellet from input film This model is for the situation where an existing recycler wishes to consider adding processing capacity for films	56,000t rigids 24,000t film (30% film) with average feed cost of £70/t (£0/t for film, £100/t for mixed rigids inc bottles) LDPE pellet price £450/t	24,000t film only Film feed cost £nil LDPE pellet price £450/t Capex £4.6m 63% overall yield	+13%	+19%	2.7	+18%	Film processing attractive as an addition to an existing recycling facility using the assumptions in this model.
Film only processing as above but with an increased feed price	56,000t rigids + 24,000t film (30% film) with average feed cost of £70/t LDPE pellet price £450/t	24,000t film only Film feed cost £20/t LDPE pellet price £450/t Capex £4.6m 63% overall yield	+8%	+12%	2.2	+9%	Film processing just viable if film feed cost is £20/t
Film only processing as above but with a greatly increased feed price	56,000t rigids + 24,000t film (30% film) with average feed cost of £70/t LDPE pellet price £450/t	24,000t film only Film feed cost £50/t LDPE pellet price £450/t Capex £4.6m 63% overall yield	0%	-7%	1.5	-5%	Film processing not attractive if film feed cost is £50/t

Table 20 Scenarios modelling only a PRF to separate baled plastics with no reprocessing facility

Scenario	Base case value	Sensitivity value	10 yr Project IRR	7 yr equity IRR	Yr5 EBITDA £m	10 yr IRR for addition of this capacity to an existing facility	Comment
Base case	-	-	+19%	+37%	9.9	-	
Near Infra Red sorting of rigid fraction only. Selling baled separated materials Throughput 56,000t/yr (Capital cost £6.4 million) This scenario models the situation where a recycler establishes a standalone PRF which takes mixed rigid plastics (including HDPE and PET bottles) and uses NIR sorting technology to produce bales of each of the polymer types in the feed. It is assumed that these baled materials are sold to other reprocessors in Europe or exported to the Far East.	56,000t rigids + 24,000t film (30% film) with average feed cost of £70/t (£0/t for films, £100/t for rigids)	56,000t mixed rigids including clear PET and natural HDPE bottles Feed cost £100/t Baled clear PET £200/t Baled jazz PET £140/t Baled natural HDPE £250/t Baled PS £140/t Baled PP £140/t Baled Jazz PE £140/t	very negative	very negative	0.4	very negative	Commercially unattractive at a scale of 56,000t/yr
Same scenario as above but with clear PET and natural HDPE already removed from feed. Lower feed cost of £40/t (Capital cost £6.4m)	56,000t rigids + 24,000t film (30% film) with average feed cost of £70/t (£0/t for films, £100/t for rigids)	56,000t mixed rigids excluding clear PET and natural HDPE bottles Feed cost £40/t	+2%	+1%	1.3	+3%	
Same scenario as first case above but with a reduced feed price for the mixed rigids	56,000t rigids + 24,000t film (30% film) with feed cost of £70/t	56,000t mixed rigids Feed cost £70/t Same sales prices as above	+14%	+24%	2.1	+22%	Return improves at scale of 56,000t/yr with lower feed price (this may be unrealistic when the feed contains clear PET and natural HDPE bottles)
Same scenario as first case above with base case feed price for the mixed rigids (£100/t) but increased throughput of 80,000t/yr mixed rigids including bottles.	56,000t rigids + 24,000t film (30% film) with feed cost of £70/t	80,000t mixed rigids Feed cost £100/t Capital cost £7.8m Same sales prices as above	+17%	+28%	2.3	+27%	Returns improve to acceptable level at higher throughput, even with feed price of £100/t

3.6 Conclusions: mixed plastics sorting and reprocessing modelling

The conclusions for the financial assessment of an integrated PRF and reprocessing facility for mixed plastics are:

- The assumptions used in the financial model produced for this report indicate that a standalone mixed plastics sorting and reprocessing plant should generate a profit at a throughput of around 80,000t/yr (24,000t/yr of mixed films plus around 56,000t/yr of mixed other rigids and bottles);
- The business would be significantly more robust to increases in feed cost or reductions in selling prices if the plant could be built with a capacity of at least 100,000t/yr (30,000t/yr films plus 70,000t/yr rigids) ;
- The commercial viability of the facility is particularly sensitive to the price of recycled pellet and to the yield of useful plastic that is extracted from the feed material. These risks would be mitigated by:
    - Careful testing of the key elements of the recycling process with the proposed feed material;
    - Clear quality and compositional specifications for the feed material;
    - Variable pricing for the feed material – linked to the price of recycled pellet. This may need to vary from positive to negative when polymer prices drop really low;
- Variations in labour and utility cost have less impact on commercial viability than product price and yield factors; and
- Variations in capital cost have a significant impact on investor returns. Grant support to reduce effective capital cost or use of second hand equipment where feasible will improve project viability.
- A mixed plastics sorting and reprocessing plant processing only other rigid plastics where clear PET and natural HDPE have already been removed should be commercially viable as a stand alone venture or as an addition to an existing reprocessing facility for HDPE and PET, provided the additional facility is built at a scale of at least 80,000t/yr.
- The assumptions used in this model indicate that film processing should be commercially viable, both as part of an integrated facility and as a standalone business. The viability of this option is sensitive to the delivered cost of the mixed film feed material. It is attractive at a delivered cost of £0/te, just viable at a cost of £20/t and not viable at a cost of £50/t.
- The sensitivity analysis indicates that a stand-alone near infra red sorting plant which produces segregated, baled containers of single polymer type for export or processing by others is not economically viable unless the feed price for the mixed rigids (including clear PET and natural HDPE bottles) is cut to around £70/t or unless the plant can be built at a scale of at least 80,000t/yr.

4.0 Overall conclusions

The financial modelling work conducted in this project leads to the following overall conclusions:

- Recycling mixed household plastics packaging appears to be commercially viable in the UK provided the integrated PRF and reprocessing facility is built at a scale of at least 80,000t/yr.
- The financial modelling exercise indicates that the ideal arrangement is for semi-automated MRFs to separate films as one fraction and mixed rigid plastics and bottles as the other or to separate PET and all other mixed rigids as two fractions with no further processing. In both cases the gate fee required for the additional mixed plastic feed to the MRF will be minimal or zero.
- If the MRF is large (over 20t/hr capacity) it may be possible to justify using NIR sorting technology at the MRF to separate clear PET and natural HDPE for sale as segregated bales.
- A fully integrated plastics recycling facility processing films, food grade clear PET and natural HDPE and industrial grade PE, coloured PET, PS and PP to produce good quality extruded pellet (with PVC baled for sale to third parties) appears to be commercially viable at a scale of about 80,000t/yr although it would be more robust at a scale of 100,000t/yr.
- Producing food grade clear PET and natural HDPE from mixed rigid feed material adds most value for the integrated PRF and reprocessing facility and allows the rigids processing element of the facility to be commercially viable at a throughput of 56,000t/yr.
- However a dedicated plastics reprocessing facility handling mixed rigid plastics which have been pre-sorted to remove films, clear PET bottles and natural HDPE bottles also appears to be viable, provided it is built at a larger scale of around 80,000t/yr.
- At current export prices for baled separated containers it appears that simply sorting the mixed plastics into different polymer types using near infra red sorters is not attractive unless it can be done at large scale (around 80,000t/yr minimum).
- Processing of mixed household films appears to be commercially viable provided baled films can be delivered to the film reprocessing plant at a cost between £0-20/t. The MRF models indicate that it should be commercially viable for a MRF to supply films to a reprocessing facility at prices in this range provided the MRF also collects and sells mixed rigid plastics

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